HYGIENE

BY

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AND

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WITH ILLUSTRATIONS

NINTH EDITION

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PREFACE TO THE NINTH EDITION

IN the preparation of this issue we have made no changes in the general plan of the work, but have revised or rewritten all sections where necessary to bring each up to date. Considerable changes have been made in the sections dealing with the theory of dietaries, the treatment of sewage, the infectious diseases and sanitary law. A short section on the sanitation of camps has been added to Chapter V., and a new chapter introduced dealing with Child Welfare and School Hygiene. Owing to some recent legislation, the chapter on sanitary law has been amplified and placed abreast of the times.

In its new form, we hope that this manual will be found to have retained its value as a plain and reliable guide to the prevention of disease.

LONDON,
January, 1921.

PREFACE TO THE FIRST EDITION

ONE of the most remarkable features in the educational movement of the present day has been the increased effort to diffuse a knowledge of the relations which exist between our health and the air we breathe, the water and food we consume, the soil we tread and the buildings we occupy. Known under the various current names of Sanitary Science, Public Health or Hygiene, this subject involves an acquaintance with such diverse sciences as physics, chemistry, geology, engineering, architecture, meteorology, epidemiology, bacteriology and statistics. To these, strictly speaking, may be added the study of the law or those legal enactments which concern the sanitary well-being of communities.

When, therefore, the publishers asked us to prepare a small work on this many-sided subject, to form one of their Science Manuals, such as would present its facts and principles fully, briefly, and yet in simple language suitable for both non-professional and professional readers, we were early confronted with the difficulty of deciding what to include and what to omit.

We have endeavoured to consider the general laws of health, the causes of disease and the means of combating them, in the simplest language, and, by divesting them, where possible, of scientific technicalities, to make clear, even to non-scientific readers, those great natural laws and processes upon which our healthy life so much depends. While doing so, we have felt bound to be not unmindful of the wants of others, desirous of entering more fully into the study of what should be a great and practical subject in our national education. The work is not to be regarded as a substitute for the regular and more advanced

books which discuss the subject of hygiene in its many bearings, but rather is intended as an introductory manual for the use of junior students or others, preparatory to a more extended and practical study of public health work.

As regards chemical analysis, we have only attempted to give such details as appeared absolutely necessary in order to make the book useful to those capable of appreciating the meaning and value of results. For their practical application, laboratory experience and instruction are essential. In order to encourage uniformity of international knowledge, the metric system of weights and measures is used.

In view of the increasing public interest taken in facts and laws concerning Weather, Climates, and Vital Statistics, short chapters have been given upon these subjects, in non-technical language as far as possible.

For illustrating some part of the text, we are indebted to Mr. L. Casella for the use of drawings of various meteorological instruments, and to Mrs. Bruce for several original diagrams. In order to further illustrate the text, use has been made of four diagrams published by the Local Government Board in their annual reports.

WOOLSTON, SOUTHAMPTON,
1894.

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HYGIENE

CHAPTER I

AIR.

We are all familiar with the fact that the earth is surrounded on all sides with a gaseous envelope, the atmosphere (from the two Greek words, ἀτμὸς, smoke, and σφαῖρα, a globe), or, as it is more commonly called, the air.

This air, when pure, is free from colour, taste, or smell, and is really a mechanical mixture of gases, possessing the properties of weight, expansion, and diffusibility. That the air we breathe is not a chemical compound, but only a mechanical mixture, is known by the facts that the gases of which the air is made up do not exist in it in their proper combining proportions, and that the relative amounts of these gases in the air cannot be expressed by any chemical formula. Moreover, on mixing the gases of which air is composed, together in the same proportions as they exist in air, there is no manifestation either of heat, electricity, or change of volume, such as would result were air a chemical combination.

The Composition and Physical Properties of Air.

The chemical composition of the dry atmosphere or air in 100 measures or volumes may be roughly taken as being 79 of nitrogen and 21 of oxygen with a small proportion of carbon dioxide. If the calculation be made by weight, there would be in 100 parts of dry air, roughly 77 of nitrogen and 23 of oxygen. As an average of many examinations, the composition of pure air appears to be as follows:—

	By Volume.	By Weight.
Nitrogen	79·02	76·84
Oxygen	20·94	23·10
Carbon dioxide	0·04	0·06
	100·00	100·00

Besides the above gases, the air always contains a certain quantity of watery vapour, together with various impurities.

Nitrogen is the main constituent of our atmosphere, and appears to act as a diluent of the oxygen, evidently reducing its strength and rapidity of action, much as water is used to dilute spirits or wine. It is probable that the nitrogen of the air may serve to supply plants with a certain amount of nourishment in the form of oxides of nitrogen, which are washed down out of the air into the soil after storms or rain, but on this point as yet very little is known.

Pure nitrogen is a colourless, tasteless, and inodorous gas: it is quite incombustible and incapable of supporting either combustion or life; it is from this latter peculiarity that foreign chemists call it *azote*, a word derived from the Greek, meaning "no life." We English people call it nitrogen, because it is the element which gives birth, so to speak, to nitre.

Nitrogen can be easily prepared from the air, by removing, by means of phosphorus, the oxygen with which it is mixed. A piece of common phosphorus is wiped dry and placed in a small porcelain capsule floating on some water contained in a dish. A light is applied to the phosphorus and the dish quickly covered with a glass bell jar. The phosphorus having a great liking for oxygen will burn until the last trace of that gas is removed from the air under the bell jar, forming as it burns white fumes of phosphorus pentoxide. These gradually become dissolved in the water, forming in it meta-phosphoric acid, while the water itself slowly rises in the dish to occupy the space originally taken up by the air, leaving the empty space above the water filled by a colourless gas which is almost pure nitrogen.

Nitrogen may also be isolated from the atmosphere by passing air slowly over red-hot copper, which absorbs the oxygen and leaves the nitrogen. About 1 per cent. of what for many years was considered nitrogen in the air, is now known to be an elementary gas called *argon*, in association with other inert gases such as *neon*, *helium*, *krypton* and *xenon*.

Oxygen.—Although nitrogen practically constitutes four-fifths of the atmosphere, the most important constituent of the air is oxygen. This gas, which when pure is clear and colourless, is necessary for all forms of life; all animals, if deprived of it, dying at once. It is also needed for every kind of combustion, such as the burning of wood or coal, and is necessary for every kind of light except the electric light. Oxygen exists in the air in a free state, and is not chemically combined with the nitrogen of the atmosphere, but only mixed with it.

Oxygen can be abstracted and recovered from the air by heating various metallic oxides and peroxides. For example, red lead, heated, gives off oxygen and leaves litharge or plumbic oxide: thus $2Pb_3O_4 = 6PbO + O_2$. Similarly, by the alternate conversion of a substance called baric oxide into a still higher oxide or peroxide by heating it in air and afterwards decomposing it by further heat, back to the original compound, a continuous process for the production of oxygen is obtained; thus $2BaO_2 = 2BaO + O_2$. The reason of being able to do this is due to the fact that barium oxide contains 137 parts by weight of the metal barium, combined with 16 parts by weight of oxygen, and if heated in purified air absorbs 16 parts more of oxygen forming the barium peroxide. If the temperature be still further raised, the extra 16 parts of oxygen are given off, and the barium peroxide returns once more to barium oxide, and can be further utilized again for the absorption of more oxygen from the air.

A modification of oxygen occurs in small traces in the atmosphere, and is known by the name *ozone.* This is a gas of probably great importance and is a kind of intensely strong oxygen. It is very plentiful in fresh pure air, and least so in places where there is much organic matter, or where men or animals are crowded together. Ozone is a powerful oxidizing agent, and is produced whenever an electrical discharge takes place in air due to the conversion of some of the atmospheric oxygen into the extremely active modification, ozone, which, however, can be reconverted into ordinary oxygen by the action of heat. Ozone may be readily recognized by its odour, which is so pungent that one volume present in $2\frac{1}{2}$ million volumes of air is said to be easily detected by the sense of smell. It is specially noticeable in country and sea air.

The most usual test for detecting traces of ozone in air is to expose strips of blotting paper moistened with a mixture of potassium iodide and starch, when if any ozone be present a blue tint is produced owing to the decomposition of the iodide and the formation of a potassium oxide and iodide of starch. This tint, however, is not very reliable, as there are often traces of other gases present in the air which give the same result. If such be suspected, in order to be quite sure that it is ozone only which has turned the paper blue, it is necessary to use a second test, which is to soak red litmus paper with a very dilute solution of the iodide of potassium. The potassium oxide produced causes an alkaline reaction, and turns the red paper to blue. Although small traces of ozone constitute a powerful agent for the purification of the air from waste organic matter, in larger quantities it acts as a violent irritant to the eyes and nose.

Carbon Dioxide.—Samples of air, no matter where collected, always contain another gas besides nitrogen and oxygen, called carbon dioxide, and this usually to the extent of about 4 volumes in 10,000 of air. Carbon dioxide is a clear colourless gas containing 12 parts by weight of carbon combined with 32 by weight of oxygen. It is produced when carbon, which forms the greater part of coal, is burnt. The carbon unites with oxygen, their union producing both light and heat with the giving off of carbon dioxide gas. For this reason, it is the invariable product of the burning of animal and vegetable matter in the air, and is he choke-damp which collects in mines after an explosion. It is also largely given off by men and animals, as well as from the earth, more particularly in volcanic districts. Under the influence of sunlight, plants breathe in carbon dioxide, retaining the carbon and setting free the oxygen. In the dark, this action of plant life is reversed, the oxygen being absorbed and carbon dioxide given off. Carbon dioxide, or as it is sometimes called carbonic acid, exists largely in Nature in combination, forming compounds called carbonates. It is readily obtained by adding dilute hydrochloric acid to a form of calcium carbonate such as marble or limestone contained in a flask, and so arranged that the escaping gas can be collected into a suitable vessel. The acid acts upon the calcium carbonate, forming calcium chloride, water and carbon dioxide; this latter escapes as a gas while the two former remain behind.

Carbon dioxide is faintly acid in taste and smell, and behaves in an exactly opposite manner to oxygen, inasmuch as it can neither support life nor combustion. It is a very heavy gas, being just 22 times heavier than hydrogen, which is the lightest of all gases. It is soluble in water, but the volume so dissolved depends largely upon temperature and pressure. The amount of carbon dioxide present in the air varies according to place and season. From 0·36 to 0·4 part per 1000 of air is found in towns, while in country districts and on the tops of hills or mountains, about 0·3 part per 1000 of air has been the average amount found in the atmosphere. In inhabited rooms and stables, of course much larger quantities have been found. To the extent of 0·4 part in 1000 of air carbon dioxide is a normal constituent of our atmosphere, and unless it exceed that quantity it cannot be considered an impurity.

Watery Vapour is always present in air. The presence of this in the atmosphere is due to the fact that water evaporates at all temperatures, so that a slow but invisible escape of water vapour is taking place from the earth's surface at all times into the air space which encircles the globe. If we leave a dish full

of water exposed to the air, it sooner or later dries up, because the water goes away slowly in the form of vapour. This phenomenon is sometimes spoken of as the tension or elastic force of aqueous vapour, and is such that it can be measured or stated to exercise pressure equal to so many inches of mercury. The amount of watery vapour which the air can take up varies with the temperature of the air, the greater the temperature the greater the amount of water vapour which can be taken up. This explains why water dries up much quicker in warm weather than in cold. Expressed mathematically, it can be said that while the temperature advances in arithmetical progression, the power of the air to retain vapour increases with the rapidity of a geometrical series having a ratio of two. When air contains the full amount of watery vapour for the given temperature it is said to be saturated; and in proportion as it is more or less removed from the point of saturation, and not in proportion to the precise amount of water it contains, is air said to be dry or moist. Thus if air can hold 100 parts of moisture, but actually only holds 75 parts, it is said to be only three-quarters moist, or to have 75 per cent. of humidity. The amount of moisture in the air can be determined by causing a current of air to flow slowly through tubes containing hygroscopic substances such as anhydrous calcium chloride or pumice moistened with concentrated sulphuric acid, which have the power of taking up or absorbing water, and then by weighing to note the increase in weight which has taken place, and knowing the exact volume of air which has been passed through, calculating the moisture present as a percentage. It is, however, more usual to determine the atmospheric moisture by means of instruments called "hygrometers," particulars of which are described in a subsequent chapter upon climate and weather.

While the amount of watery vapour in the air has a considerable effect upon the temperature of a place, its presence is absolutely necessary for life. A perfectly dry air not only would be unbearable, but would quickly prove fatal to both plants and animals. As a rule, the atmosphere contains from 1 to $1\frac{1}{2}$ per cent. of water in a state of vapour, or from 50 to 75 per cent. of the amount required for complete saturation. If the quantity be much above or below these limits, the air is either unpleasantly moist or dry.

The air being really nothing more than a mixture of gases, behaves exactly as and has the properties of a gas; that is to say, it has weight, expansibility, and diffusibility. Like any solid or liquid, the air has **weight**. That this is the case is shown by the fact that if a glass globe of known capacity be taken, exhausted

of all air by means of an air-pump and then weighed, its weight then will be less than it would be if air were allowed to enter it. If the capacity of the globe be known, the difference between the two weights is the weight of that volume of air. By a modification of this method, and the exercise of certain precautions, the weight, not only of air, but of other gases, has been accurately determined.

Since the air has weight, it gives rise to *pressure* according to the same laws as those by which the weights of liquids produce pressure. If we imagine an upright cylinder, some miles in height, full of air and resting upon the ground with its top closed, and consider the air contained in the bottom ten feet of the cylinder, we can readily realize that this lower portion of air must support the weight of all the air above it, and transmit that weight to the ground beneath it, and also to the curved sides of the cylinder which contain it, and that in a direction at right angles to the surface. Thus the pressure of the air in this imaginary cylinder increases from the top of the column to its base, and is equal to the weight of that column.

If we regard the atmosphere as a kind of fluid sea, some 40 miles in depth, surrounding the earth on all sides, we can realize that it exercises the same pressure as if it were a liquid of very small density. This pressure will be at right angles to any surface, and will lessen as we ascend from, and increase as we descend to, the level of the earth. Since experiments show that the weight of 100 cubic inches of air is no less than 31 grains, it will be easily understood that the whole earth's atmosphere, which has been estimated to be not less than 40 miles in height, really exercises a very great pressure upon the earth's surface. The exact amount of this atmospheric pressure was first determined by an experiment made in 1643 by Torricelli, which may be explained as follows:—A glass tube, closed at one end, is taken, having an internal diameter of $\frac{1}{4}$ inch, and being a yard long. After filling it quite full of mercury, and then stopping up its open end firmly with the finger, turn it upside down, and insert its open end into a vessel containing mercury. As soon as the finger is removed, the mercury will be seen to fall slowly in the tube, until, if the observation be made in the south of England, it stands about 30 inches higher than the surface of the mercury in the vessel. This vertical column of mercury will remain at 30 inches, in height, because it is prevented from falling any lower in the tube by the counterbalancing weight or pressure, as it is called, of the air. If this same experiment be performed on the top of a mountain or high land, the length or height of the mercurial column supported by the air will be less than 30 inches, because at elevated places the height and

consequently counterbalancing weight of the atmosphere is less than at places at a lower level.

By a law of hydrostatics, the heights of two columns of liquids in communication with each other are inversely as their densities; hence it follows that the pressure of the atmosphere is equal to the weight of a column of mercury, the height of which is 30 inches. If, however, the weight of the atmosphere diminishes, which it does do in elevated places, the height of the column which it can sustain must also diminish. In the foregoing experiment, the sectional area of the tube may be taken to be equal to one square inch, and since the height of the column of mercury is 30 inches, the mercurial column is really one of 30 cubic inches. As a cubic inch of mercury weighs $343\frac{1}{2}$ grains, or as near as possible half a pound, the pressure of that column of mercury on each square inch of surface is equal to $14\frac{3}{4}$ pounds. On a square foot, this would give a pressure of nearly a ton; and as the average superficial area of an ordinary man is 16 square feet, the pressure supported by such a man amounts to nearly 16 tons. This at first sight seems an impossible burden, but the effect of this enormous force is equalized by the contrary and equal pressure of it in all directions upon the body surface, whereby we are rendered totally unconscious of its existence. The instruments used for measuring atmospheric pressure are called barometers; their varieties and special features are discussed in a subsequent chapter.

Though the total weight of the atmosphere must always be the same, still its density, and consequently the pressure which it exerts, will vary according to local conditions. The most prominent of these conditions are its temperature and its degree of dryness. Like every other gas, air expands with heat, and assuming no variation in pressure, this is at the rate of $\frac{1}{491}$ or 0·00203 of its volume for each degree Fahrenheit; or $\frac{1}{273}$ or 0·00367 for each degree Centigrade. For this reason, a given volume of air at 50° F. is lighter than the same volume at 40° F.; and a cubic foot of air at 0° C. would weigh just twice as much as a cubic foot of air at 273° C. Similarly, moist air is lighter than dry air. The reason of this is as follows:—Air is really a mixture of 4 volumes of nitrogen (atomic weight being 14) and 1 volume of oxygen (atomic weight being 16). Each volume of air, therefore, is represented by $\frac{4 \times 14 + 16}{5} = 14{\cdot}4$. Now, moist air is air, *plus* water, in a gaseous or vaporous state; but water itself is a compound of 2 volumes of hydrogen (atomic weight 1) and 1 volume of oxygen, and as a compound gas, occupying 2 volumes, is represented by

$\frac{16 + 2}{2} = 9$. That is to say, a volume of dry air weighs 14·4 and one of water vapour only weighs 9. These variations in the weight of hot or cold, dry or moist air are indicated by corresponding fallings or risings of the barometer, and explain why in England the barometer rises during dry easterly winds and usually falls with the damp westerly winds.

The **Expansibility** of air, which plays a very important part in the theory and practice of ventilation, as we shall see later on, is really dependent upon two conditions; namely, the pressure under which it is, as expressed by the barometer, and the temperature at the time being. For a due appreciation of this power of air to constantly change its volume, it is necessary to understand and apply the two physical laws of Boyle and Charles. The law of Boyle is, that "the temperature remaining the same, the volume of a given quantity of air or gas is inversely as the pressure which it bears." In other words, this means that if a cubic foot of air is measured at 29 inches of barometric pressure, to know what it would measure, were the pressure 30 inches, it must be multiplied by 29 and divided by 30. Or, that a quantity of air which exactly measured 1 cubic foot at 29 inches of barometric pressure would only measure 0·96 cubic foot had the pressure been 30 inches, because $1 \times \frac{29}{30} = 0{\cdot}96$ cubic foot.

The law of Charles is, that "assuming no change in pressure, any gas or air expands or contracts $\frac{1}{491}$ (·00203) of its volume for every degree it is above or below 32° F. in temperature." If the temperature be on the centigrade scale, the ratio of expansion or contraction is $\frac{1}{273}$ (·00367) for each degree above or below 0° C. In other words, this means that 491 volumes of air at 32° F. become 492 at 33°, 493 at 34°, and so on. That is, as 491 *plus* or *minus* the given temperature is to 491 *plus* or *minus* the required temperature, so is the given volume to the required volume. As an example, we can say 100 volumes at 30° F. will become 104·09 volumes at 50° F.: because as $491 - 2\ (489) : 491 + 18\ (509) :: 100 : x = 104{\cdot}09$ volumes.

In actual practice, it is usually needed to make these two calculations or corrections together. For instance, suppose in a room with the temperature at 40° F. and the barometer at 30 inches, the volume of air was 1000 cubic feet, what would be the volume of that same air were the temperature to be raised to 60° F. and the pressure fall to 29 inches? Using the two equations combined, as follows—

$$\frac{30}{29} \times \frac{491 + 28}{491 + 8} \times 1000 = 1075 \text{ cubic feet,}$$

we get that, under these altered conditions of pressure and temperature, what before measured 1000 cubic feet now measures 1075 cubic feet, consequently the excess of 75 cubic feet would escape out of the room.

It is only by rightly comprehending the great property of the atmosphere to expand or contract according to the above-mentioned laws, that we can fully appreciate the causation or production of those movements of the air over larger or smaller regions which we in everyday life call winds or draughts. They are due to the simple fact, as already explained, that when over some large tract of land the air is warmed by the sun, it expands and rises, while from adjoining regions colder and heavier masses of air rush in to take its place. Similar but smaller movements of air, due to varying degrees of heat, density, and pressure, are constantly going on in and about our houses. It is the same cause which makes the warm air over a fire go up the chimney to be replaced by fresh and colder air entering by windows, doors, and cracks. Whenever a room or house is inhabited by human beings or warmed by lights and fires, a constant expansion of air is going on with an escape of the excess volume by the chimneys and doors or windows. By this means the equilibrium between one part of a dwelling and another is constantly being disturbed, and the air rarely if ever allowed to be absolutely still even over the most limited area.

From what has already been said, it will be gathered that, while the atmosphere has several constituents, each of them has its own particular weight; that while the carbon dioxide is heavier than the oxygen, this again is heavier than the nitrogen, and the water vapour is lighter still. There is, however, no formation of layers of the various constituents of the air, that is the heaviest at or near the ground and the lightest above. Owing to the diffusion of gases under well-known laws, the various constituents of the atmosphere tend to mix one with the other, with the result that we find them equably distributed.

The **Diffusibility** of a gas is well and easily shown by the following simple experiment: Take a **U**-shaped tube some 18 inches long, fix it at one end by a cork to a porous cell such as is used in electric batteries, and then fill the tube nearly full with some water. Next make some hydrogen, and fill with it a bell jar. If this bell jar containing the hydrogen be quickly placed over the porous pot, the hydrogen gas so rapidly diffuses through the pores of the cell or pot into the tube that the water is at once driven down, and spurts out at the open end. So, again, if we take two globes, and, having filled the lower one with carbon dioxide and the upper with hydrogen, connect them together by a

tube, although the hydrogen was in the upper globe, yet, after a short time, half of it will have gone down into the lower globe and half of the carbon dioxide will have ascended into the upper one. Now we know carbon dioxide to be just 22 times as heavy as hydrogen, yet the power of diffusion is so great that it has overcome the enormous force of gravity.

The rate at which this intermingling of gases can occur is largely influenced by their weights (densities). So much so that, according to the law of Graham, it is enunciated that "the force of diffusion is inversely as the square roots of the densities of gases." Thus, if we take two vessels of equal size, the one containing oxygen and the other hydrogen, and separate them by means of a porous plug, we shall find diffusion take place, and this will be in the proportion of 4 parts of the hydrogen into the oxygen to every 1 part of the oxygen into the hydrogen. This exact ratio of diffusion is explained by the fact that the density of the hydrogen is 1 as compared with the 16 of oxygen, hence the force of the diffusion is inversely as the square root of these numbers—that is, it is inversely as 1 is to 4, or just four times as great in the one which has one-sixteenth the density of the other.

It is this faculty of diffusion, possessed by all gases, which is the chief cause by which the composition of the air is kept constant, and which causes the carbon dioxide formed so freely in our large towns and cities by combustion and breathing to be rapidly removed from where it is formed to other parts, where the processes of vegetation and sunlight can break it up into carbon for the food of plant life and oxygen for the use of men. It is this remarkable action of the green colouring matter of plants, called chlorophyll, upon carbon dioxide, which is the great compensating agency at work for keeping down the tendency of carbon dioxide to increase, and whereby Nature gets rid of what practically is the chief impurity in the air, with the result that the carbon dioxide in the atmosphere at the top of a mountain is in much the same proportion as in the air at its foot—namely, that it rarely reaches a proportion of more than 0·04 per cent., an amount which is quite harmless to human life. Supplementary to the power of gaseous diffusion, we have the action of winds, which scatter and diffuse over a large area many impurities of the air which would be very hurtful if confined to any limited space. In a similar but lesser sense, dew, rain, and snow may be regarded as helping in the constant purification and dispersion of atmospheric impurities.

THE IMPURITIES OF THE AIR.

Although the examination of pure air indicates it only to consist of nitrogen, oxygen, a definite amount of carbon dioxide, not exceeding 0·04 per cent., and some watery vapour, the majority of samples of ordinary air betray the presence in them of various impurities, notably traces of ammonia, nitric acid, nitrous acid, various compounds of carbon—chiefly carbon dioxide, carbon monoxide and carburetted hydrogen,—with a greater or less amount of suspended matter, such as soot, dust, epithelial cells, vegetable fibres, wool and silk fibres, particles of sand, chalk, or iron, and the minute forms of life. These impurities of air are mainly the results either of combustion, respiration, emanations from sewers, marshes, or graveyards, or else the contaminations given off by manufactures and trade processes.

Ammonia is a compound containing 14 parts by weight of nitrogen along with 3 parts by weight of hydrogen. It is a colourless gas, marked by an intensely pungent odour, and quite unable to support combustion. Although traces are usually present in most air samples, it rarely exists in the atmosphere in greater amount than 3 parts in ten million, and is formed in the main from the decomposition of decaying nitrogenous matter. When present, ammonia is usually in combination with some acid, such as nitric or carbonic. Being readily soluble in water, ammonia is quickly washed out of the air by rain, and carried down into the soil, in which it affords a valuable food for plants. Chemically, ammonia represents the main part of what is called the organic matter in the air, and if dissolved in water, yields the so-termed albuminoid ammonia.

Nitric and Nitrous Acids are probably derived by the air in small quantities from decaying nitrogenous matter, while, too, a certain amount is produced in the air by the direct combination of oxygen and nitrogen during electrical disturbances. These acids, like ammonia, are washed down by rains into the soil, and there serve in the fertilization of various forms of vegetation.

Carbon Dioxide has already been shown to exist to a limited extent in pure air. This limit has usually been placed at 0·04 per cent., or 4 parts in 10,000 of air; but it is probable that this limit is too high, and that in the purest airs the natural amount of carbon dioxide does not exceed 0·3 per 1000 volumes. Any carbon dioxide present in air, therefore, over and above 0·04 per cent., must be regarded strictly as an atmospheric impurity. This gas we know to be largely given off into the air by men and animals during breathing, by all processes of combustion or putrefaction,

and by certain kinds of soil; it is increased by fogs, but lessened by rain, winds, vegetation, and ventilation. The amount in the air is consequently variable.

In some places the air often contains as much as from 2 to 5 parts per 1000; on the other hand, the air in a London street on a breezy day has been found to have as little as 0·36 per 1000. Carbon dioxide in its pure form is fatal when present to the extent of 75 parts per 1000, while 15 parts per 1000 gives rise to giddiness, faintness, headache, and shortness of breath; anything below 10 parts per 1000 appears to produce no effect immediately on health. In fatal quantities the action of carbon dioxide is that of a narcotic poison producing insensibility and deep sleep. The amount of carbon dioxide given off by respiration is estimated by deducting the amount present in the outside air, or, what is usually the same thing, 0·04 per cent. from the total carbon dioxide present. Thus, if in a hospital ward or schoolroom the air was found to contain 0·78 of carbon dioxide per 1000 parts of air, deducting 0·4 as being normally present in the atmosphere, we should have 0·38 part per 1000 as a carbon dioxide impurity due to respiration and other causes. We are all familiar with the heavy unpleasant smell or stuffy feeling present in all ill-ventilated or crowded rooms. In connection with this it has been observed that anything under 0·2 part per 1000 over and above the 0·4 usually present in the air—that is, a total of 0·6 per 1000—is not associated with any atmospheric impurity capable of being perceived by the sense of smell. For this reason, this quantity is regarded as unavoidable and harmless, and, as such, a permissible impurity. The moment the carbon dioxide exceeds this quantity, the accompanying organic and impure matters present in the air become perceptible—so much so that the following scale has been proposed, namely, "rather close" = 0·4; "close" = 0·6 (1·0 total); "very close" = 0·8 (1·2 total); beyond this amount the sense of smell does not seem able to distinguish. The temperature and degree of moistness of the air have an influence upon the readiness with which the smell of organic impurities is perceived. In order to correctly judge the extent of atmospheric foulness by the sense of smell, it is necessary that the observer should have been at least some half-hour or so in the outer or fresh air, as the sense of smell is very rapidly dulled by foul air—so much so that the occupants of rooms containing impure air are rarely aware of its state.

Though the prolonged stay in crowded or ill-ventilated rooms whose atmosphere is markedly impure, as evidenced by a high ratio of carbon dioxide, is invariably associated with headaches, faintness, giddiness, etc., it is not to any organic fouling of the

air, or even to the carbon dioxide itself that these ill effects are due. The outcome of recent inquiries indicates that the main cause of the evil results which follow the breathing of used air is the increase of moisture and heat combined with a diminution of the oxygen, which is so characteristic of the air of ill-ventilated spaces. In Hill and Flack's experiments, eight adults were imprisoned in a small chamber holding about 3 cubic metres of air, and kept there until the CO_2 reached from 3 to 4 per cent. and the oxygen had fallen to 17 per cent. and the moisture risen to 95 per cent. Although the discomfort was severe, it was relieved to an astonishing extent by simply whisking the air by fans, and so cooling the bodies of the imprisoned persons; still greater relief was secured by cooling the air by means of cold water allowed to circulate through an attached radiator. These experiences indicate the discomfort to have been due, not to chemical impurities, but to excessive heat and humidity.

The continuous breathing of an undoubtedly vitiated atmosphere is not less hurtful to health. It induces a general lowering of the vital processes, with loss of strength and nutrition, to say nothing of an indirect influence towards both physical deterioration and general moral degradation. It is only too probable that to this cause, as much as to defective feeding, must be attributed the impaired vitality and health of many of the poorer inhabitants of our crowded towns and villages.

While, of the carbon compounds found as impurities in air, carbon dioxide represents the main impurity due to respiration and combustion, there are several other gaseous impurities constantly added to the air as the result of the combustion of coal, coke, coal gas, etc. Among them are carbon monoxide, carburetted hydrogen, sulphurous acid, and sulphuretted hydrogen.

Carbon Monoxide is a gas produced by the combustion of carbon in an atmosphere of carbon dioxide, and is frequently formed on the surface of charcoal stoves not exposed to air currents. This gas is extremely noxious, less than 0·3 volumes per cent. being able to produce poisonous symptoms, such as dizziness, headache, confusion of ideas, with a feeling as if a tight band encircled the forehead and temples. In extreme cases, this gas causes suffocation by displacing the oxygen out of the red corpuscles in the blood. The presence of carbon monoxide is always a sign of imperfect combustion, such as occurs when coke is burnt in an open grate, and is especially apt to be generated by cast-iron stoves. This appears to be due to the fact that a portion of the carbon dioxide evolved during the combustion of carbon is changed by heated iron into carbon monoxide, and that heated iron, more particularly cast iron, while generating

and absorbing this gas by its internal surface, permits it to diffuse continuously from its external surface into the surrounding air. It is chiefly owing to this fact that the employment of stoves in this country has never been regarded with favour.

Carburetted Hydrogen, though often present as an impurity in air, as the result of combustion of coal, is a comparatively harmless gas. It is often present in small quantities in mines, and appears to do no harm. In large quantities, such as 300 parts per 1000, it seems to produce some poisonous symptoms, such as vomiting and convulsions. From its occasional presence in the air over marshes, this gas is often called "marsh gas." Another name for it is "methane."

Sulphur Dioxide and sulphuretted hydrogen are, among other impurities, added to air by combustion processes. The former is a constant impurity in the air of coal and gas burning towns, where it often exists in sufficient quantity as to redden, after a few hours' exposure, moist blue litmus paper. The presence of this gas in the air of large towns is one of the chief causes of the difficulty experienced in cultivating shrubs or trees; while, too, when washed down by rain, it materially retards the growth of grass.

Sulphuretted Hydrogen, which is a disagreeably smelling gas, may be found in the neighbourhood of gasworks, chemical factories, sewers, and marshes. In mines it often exists from the decomposition of iron pyrites. As a rule, this gas has no ill effects upon health, but a few cases have been reported, in which the continued breathing of this gas has given rise to serious symptoms. In acute cases, these appear to be those of a narcotic and convulsive poison; while in chronic cases, more of the nature of anæmia, diarrhœa, and general sickness.

Suspended Matter.—The impurities of the air which we have so far considered are only gases, and, on the whole, generally diffused or distributed; but, besides these, there are certain impurities which are more or less solid, and only exist at or near the spot where the cause for them is to be found. We are all familiar with the fact that, if a beam of sunlight pass through a chink or crevice into a darkened room, its course is made visible to us by some of the light being reflected by minute particles of suspended matter. The particles which comprise this suspended matter, or solid impurities of the air, are of the most varied nature: some of them are inorganic, some organic, some absolutely harmless, some truly hurtful. Except in certain places, such as on the top of mountains or out at sea, it is difficult to find any air which is absolutely free from all suspended matter, while in towns

and factories the atmosphere is usually heavily laden with many solid particles. How far these suspended matters or impurities in the air will affect our health, depends much upon their quality or nature, and not so much on their mere quantity; but this latter, in some cases, is not a negligible point. Chief among the *inorganic* suspended matters of the air will be found fine grains or particles of sand, coal or carbon, clay, common salt, and oxides of iron. As a rule, these solid inorganic suspended matters of the air, consisting of dust of various kinds, though extremely injurious to health if in excess, are only so by virtue of their mechanical irritating influences upon the eyes and lungs. It is their physical conditions as to roughness, angularity, or smoothness, rather than their mere nature, which influences their power for evil. Various affections of the lungs, notably phthisis, or consumption, have been traced among classes of work-people as being due to the breathing in by them, during work, of the finer dust products of their particular trades or businesses. For instance, among tin-miners lung disease is prevalent, owing to the fine particles of tin-dust inhaled by these workers; similarly, the fine dust from iron mechanically irritates the air-passages, and gives rise to considerable ill-health among needle-makers, saw-grinders, and cutlers. So, too, among potters, a peculiar asthmatic cough is often set up in consequence of the continued breathing of the finer clay dust. The makers of cement, grindstones, and certain kinds of glass suffer in the same way. In white-lead works, the lead dust gives rise to colic amongst the workers, while workers in copper and brass foundries are subject to a special form of non-periodic ague, and among match-makers the fumes and particles of phosphorus used in making matches, when inhaled, are apt to give rise to disease of the maxillary bones.

The *organic* suspended impurities of the air vary, even more than the inorganic, with the locality, both in kind and number. Among the more common are starch cells, pollen grains, and minute seeds of plants, pieces of wood, fine fragments of flax, wool, cotton, and silk, together with fatty particles, scales of hair or skin, and germs of disease. The majority of these are, of course, harmless. That the disease known as hay fever or summer catarrh is produced in many by the pollen from grasses is too familiar to be doubted. In the carding-rooms of cotton, flax, wool, and silk factories the finest dust from off the special fabrics is often so great and so irritating in nature in the atmosphere of the work-rooms that considerable ill-health results to those employed in them. Though it is somewhat disgusting to think that particles of fat and scales of hair or skin are floating

about in the air, that such is the case is none the less true, and is, moreover, a not infrequent means of carrying disease from one person to another. Thus pus cells from ulcers and sores may give rise to a very infective form of inflammation of the eyes or even erysipelas, and the dried particles of expectoration from the lungs of those suffering from consumption, floating in the air, can convey that disease to those compelled to breathe such tainted atmosphere: in a similar way, infective matter from those sick with smallpox, scarlet fever, or measles may carry these diseases to the healthy. Though the germs of disease thus capable of being carried from one person to another by floating through the air can only doubtfully be supposed to find any nourishment and actually grow in the air, there is a possible risk of their being able to retain their vitality while thus suspended in the atmosphere. How soon or how readily they may infect any one depends upon the different degrees of resisting power of the particular germs and of the individual who may inhale them.

Numerous experimental observations have indicated that from 1 to 22 micro-organisms per litre of air are present in the atmosphere of four-roomed houses in excess of those present in the outside air, and that in very small tenements, consisting of only one or two rooms, the excess is from 6 to 240 per litre of air. Without attaching too much importance to the actual number of micro-organisms found or present in the air, it appears that the proportion between the moulds and bacteria present is a matter of considerable interest. The ratio of bacteria to moulds increases with vitiation of the air, because bacteria come principally from the walls, floors, and occupants of a room, while the moulds come principally from the outside. While in the outer air, the bacteria may stand to moulds in the ratio of only 2·5 to 1, in four-roomed houses the ratio is often 21 to 1, in single-room tenements 49 to 1, and in crowded and imperfectly ventilated public rooms, such as school, as much as 132 to 1. Experience suggests that in a properly ventilated space the bacteria should not exceed moulds in a greater ratio than as 30 to 1, and that the total number of micro-organisms should not exceed 20 per litre of air.

Sewage Emanations.—Air rendered impure by emanations from sewage, whether from drains, sewers, or cesspools, is undoubtedly capable of giving rise to ill-health, more especially in the form of sore throats (diphtheritic or otherwise), diarrhœa, and gastro-intestinal disturbance. The composition of such air is such that its oxygen is lessened, its carbon dioxide increased, and that there is much organic matter together with varying amounts of sulphuretted hydrogen present. The numbers of micro-organisms present in the suspended matter of such air is not always

increased. How far the bad effect following exposure to sewage-polluted atmosphere is due to any one individual impurity is uncertain, but the evidence is strong that either some specific poison is carried by sewer emanations to the general atmosphere, or else their effect is powerfully to predispose to disease. It is probable that sewer emanations differ largely in their specific powers for evil, according as to whether the generating sewer be adequately ventilated or not, as evidenced by the good health enjoyed by men working in well-ventilated and well-constructed sewers as compared with those employed in sewers which are ill-ventilated and otherwise faulty.

Marsh Emanations.—Marshes have long had ill-repute owing to the prevalence of malaria in their vicinity. In the light of modern knowledge, this connection of malaria with marshes depends, not upon any special emanations of gases, but upon the fact that water-logged lands and marshes afford suitable breeding-places for certain kinds of gnats, or mosquitoes, which are necessary for the diffusion of the malarial micro-organism from man to man.

The air of **Brickfields** and **Cement Works**, though usually characterized by a distinct smell, cannot be shown to be sanitarily impure. The exact cause of the odours prevalent is not known, and though the air issuing from the chimneys of furnaces and kilns is rapidly fatal, so rapidly is it diffused and diluted that at a very short distance it is quite respirable. The chief evil of the smoke and gases escaping into the air from cement works appears to be its destructive effect upon all adjacent vegetation.

In former years, much atmospheric pollution occurred in the neighbourhood of copper, alkali, and chemical works generally, from the pouring out of fumes of sulphurous, sulphuric, and hydrochloric acids, along with sulphuretted hydrogen and ammonium sulphide. At the present day this has to a great extent been remedied.

The Theory and Practice of Ventilation.

From the preceding pages we have learnt that, while the average composition of pure air is practically constant, the nature of the impurities in the atmosphere is less so. In the ordinary sense in which the term ventilation is used, we may regard it as the removal or dilution of all the impurities which can collect in the air of inhabited rooms. These impurities, we have seen, may be derived from various sources, such as respiration, exhalations from the skin, the combustion of fires and lights, the presence of filth, dirt, or putrefying matter, and even the escape of emanations

from sewers, drain-pipes, and other impurities under or outside our houses.

In practice, we may limit the term ventilation to the dilution or removal, by a supply of pure air, of the products of respiration and of combustion in ordinary dwellings, coupled in the case of hospitals with the additional impurities resulting from the presence of sick persons. For the removal of all other air impurities, ventilation ought not to be required, because, strictly speaking, these should be avoided by the exercise of due cleanliness and the maintenance of a proper system of drains and sewers, combined, moreover, with a general attention to the sanitary condition of the neighbourhood of our houses. Before proceeding, however, to determine how much fresh air is required for the above-named purpose, and as to how this supply can be best attained, it is necessary to inquire with some detail what are the precise amounts of the impurities added to the air of our houses as the results of both respiration and artificial lighting and warming. To a large extent these latter may be ignored, as the products of the combustion of coal, used in artificial heating, escape for the most part by the flue of a stove or by the chimney of an open grate, and as such, do not materially add to the contamination of the atmosphere of a room; it is therefore unnecessary to enter into any great detail regarding them.

Impurities due to Respiration.—It will be a material aid to our conception of the amounts of the impurities added to the air by respiration, if we recall the facts that while the air breathed into our lungs contains about 79 per cent. of nitrogen, 21 per cent. of oxygen, and 4 parts in 10,000 of carbon dioxide, the air breathed out by the lungs contains 79 per cent. of nitrogen, about 16 per cent. of oxygen, 3 to 4 per cent. of carbon dioxide gas, and some $1\frac{1}{2}$ per cent. of watery vapour, the remainder consisting of organic matter. In other words, this means that the oxygen has been lessened by about one-fourth, the carbon dioxide increased just about one hundred times, with the watery vapour, ammonia, and organic matter also increased.

A healthy adult man at rest breathes from 14 to 18 times a minute, and allowing that at each inspiration 25 cubic inches of air are taken in, the total quantity of air which passes into and out of the lungs in the twenty-four hours is about 648,000 cubic inches or 15·6 cubic feet in each hour. This amount is, however, largely increased by exertion, and may, in the case of a man doing great labour, reach as much as some 1,600,000 cubic inches in the same time. If we assume that the expired air contains only 4 per cent. of *carbon dioxide*, the average man at rest evolves nearly 16 cubic feet of this gas in the twenty-four hours, or 0·66 cubic foot

per hour; during hard work the amount evolved is something like 37 cubic feet in twenty-four hours, or say 1·6 cubic foot per hour.

The quantity of *watery vapour* given off from the body is greatly influenced not only by the different degrees of muscular exertion and repose, but also under the ever-changing degrees of moisture of the atmosphere. Speaking roughly, 10 ozs. are given off by the lungs and some 20 ozs. by the skin in the day. This is equivalent to about 550 grains per hour. If we assume the average temperature of occupied rooms to be 60° F., this means enough moisture is given off by the human body every hour sufficient to saturate 90 cubic feet of air. It is this tendency to become saturated with moisture from the lungs and skin that makes the air of crowded and unventilated rooms so uncomfortable. Carnelley's experiments show that for every part of carbon dioxide found in the air, 2·7 volumes, or 1·1 part by weight of moisture, have been given off by each person inhabiting the room.

As already explained, although the carbon dioxide added to the air by respiration and other processes is not of itself a very great impurity, yet it occurs in such constant relationship with the rise in temperature and moisture as to be taken and accepted as the most convenient index of the amount of the general impurities added to the air by respiration. The amount of this gas, then, given off daily by an ordinary man in repose may be taken to be some 16 cubic feet, or 0·66 cubic foot per hour; in light work it is about 0·95 cubic foot, and in harder work from 1·6 to 1·95 cubic foot per hour. In the case of females, the figure is about 0·5 cubic foot, and for a child 0·3 cubic foot; or, as an average for a mixed community, 0·6 cubic foot may be accepted.

Impurities due to Artificial Lighting.—Turning now to the question of the precise amounts of impurity added to the air consequent upon artificial lighting, we find that the chief sources of light are candles, oil, and coal gas, and that the chief products of the more or less complete combustion of these illuminants are carbon dioxide and water, with the addition, in the case of gas, of several products of the combustion of sulphur. Now, the unit adopted in this country for the measurement of all lights is a sperm candle of a size known as "sixes," burning 120 grains per hour, and which gives a light known as "one candle power." Such a candle, on analysis, is found to contain—

Carbon	80·0 per cent.
Hydrogen	13·0 ,,
Oxygen	6·6 ,,

and on complete combustion yields equal volumes of carbon dioxide and water to the air, namely, 0·41 cubic foot.

The French unit of light is the light given out by one Carcel burner, and equals 9·3 English standard candles.

What is known as Vernon Harcourt's standard flame gives a light equal to that of one English standard candle. It consists of an air-gas flame, $2\frac{1}{2}$ inches in height, rising from an opening $\frac{1}{4}$ inch in diameter. The flame is that of a mixture of air and pentane: 576 volumes of air being mixed with one of liquid pentane at 60° F.; or, if both are in the form of gas, 20 of air to 7 of pentane. Pentane is a hydrocarbon occurring in petroleum and in the light oil obtainable from Cannel coal.

Although various kinds of oil have been employed for illuminating purposes, paraffin, owing to its cheapness and high illuminating value, is the only one in extensive use. Ordinary paraffin, on analysis, gives the following composition:—

Carbon	86·0 per cent.
Hydrogen	14·0 ,,

When burnt in the better kinds of lamp, the average consumption per candle power of this oil is just 62 grains per hour, giving off on combustion in that time 0·28 cubic foot of carbon dioxide and 0·22 of a cubic foot of water vapour. Formerly, rape-seed or colza oil was largely used for lamps, but now it is replaced by the mineral oils, paraffin and petroleum. Colza oil is remarkably safe, but is expensive, and needs a special lamp for its use, owing to its viscid nature and the difficulty in getting it to ascend the wick.

All oil-lamps should have a suitable reservoir for the oil. This should always be made of metal and not of glass or china, as these latter break easily and cause the oil to escape. The reservoir ought to hold at least half a pint of oil for each wick in the lamp. It should never be filled quite up to the top, nor be allowed to burn quite dry. If too full, the oil may overflow and catch fire; or when burnt to the last drop, the smouldering wick may set fire to an explosive mixture of oil-vapour and air which tends to collect inside the empty and hot lamp. Much of the success of oil-lamps depends upon the proper regulation of the draught to the flame by the length of the chimney and the placing of a suitable inlet for air through a perforated metal plate below. These are points usually seen to by the makers. Defects of this nature check complete combustion of the oil, and are the cause of the lamp smelling. All lamps should be provided with a patent extinguisher.

The chief popular illuminant is gas. Ordinary gas is obtained by the destructive distillation of coal, free from contact with the air, and consists of a mixture of several gases, varying largely, of course, upon the kind of coal used and the methods of purification. The following statement of the analysis of two London gases made by Professor Lewes may be accepted as fairly representing the composition of coal gas generally:—

	South Metropolitan Gas Company.	The Gaslight and Coke Company.
Hydrogen	50·16	53·36
Saturated hydrocarbons	36·25	32 69
Unsaturated ,,	3·50	3·58
Carbon monoxide	5 68	7 05
Carbon dioxide	0 00	0·61
Nitrogen	4 10	2·50
Oxygen	0·31	0 21
	100·00	100·00

These constituents of coal gas may be divided into three groups—the illuminants, the diluents, and the impurities. The *illuminants* are hydrocarbon gases, more particularly ethylene or olefiant gas, acetylene, and benzene vapour; they constitute about 4 per cent. by volume of the coal gas, and are referred to above as unsaturated hydrocarbons. The *diluents* are gases which, without conferring much luminosity on coal gas when burnt, yet serve the important purpose of diluting down the heavy hydrocarbons, which by themselves would yield a smoky flame. They are hydrogen, carbon monoxide, and saturated hydrocarbons such as methane or marsh gas. The *impurities* consist of nitrogen, derived from a little air getting into the retorts when opened for the purpose of recharging, and of some carbon dioxide, and traces of sulphur compounds, which may have escaped removal in the purifiers. It is forbidden by law that gas contain any trace of sulphuretted hydrogen. In future all gas will be sold to the public and judged by its calorific value in terms of thermal units produced by the combustion of one cubic foot of the gas measured at 60° F. under a pressure of 30 inches of mercury and saturated with watery vapour.

Every cubic foot of ordinary coal gas yields on combustion roughly 0·52 cubic foot of carbon dioxide and 1·3 cubic foot of watery vapour; whilst the lighting power of gas per cubic foot depends upon the particular burner employed.

Speaking generally, there are two principal kinds of burners in use, namely, the flat-flame and Bunsen burners. Flat-flame burners are of two chief kinds, known respectively as the fish-tail and the bat's-wing. The fish-tail (Fig. 1) consists of

an iron nipple perforated by two holes, drilled so that the jets of gas are inclined towards each other at an angle of 90°. A flat flame is thus produced, and somewhat resembling the tail of a fish. The bat's-wing (Fig. 2) consists of a similar nipple perforated by a fine slit, giving a flat, fanlike flame. In the best forms of all kinds of burners now in use, steatite or pottery tops are employed. The common metal and steatite burners in use permit the current of gas to strike against the orifice without any control or regulation, but in the numerous patented forms of both fish-tail or bat's-wing burner, a certain mechanical obstruction or governor is inserted, which breaks or retards the gas current, to ensure more complete combustion. The illuminating power of a good fish-tail or bat's-wing burner equals 16 candles, with an hourly consumption of something like 4 or 5 cubic feet of gas per hour; but the great majority of flat-flame burners in common use of the size known as 4 or 5, and popularly supposed to

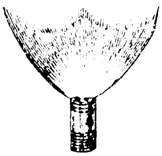

FIG. 1.—Fish-tail burner.

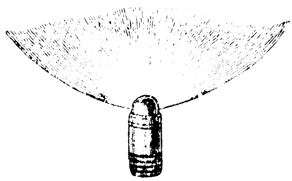

FIG. 2.—Bat's-wing burner.

consume respectively 4 and 5 cubic feet of gas per hour, really consume nearly double that amount of gas, and at the same time yield an extremely low degree of light.

The actual products of combustion given off by gas will, of course, vary much with the quality of the gas used and the completeness of the process. The usual products of the combustion of gas are: carbon dioxide, carbon monoxide, compounds of ammonia, watery vapour, and various compounds of sulphur. These latter, if present, are particularly injurious to health, but there is reason to believe that their existence in gas-lit rooms has been much exaggerated. For every 100 cubic feet of gas consumed, containing 20 grains of sulphur, there would be 0·032 of a cubic foot of sulphur dioxide formed, while with an impurer gas containing 30 grains of sulphur per 100 cubic feet, the sulphur dioxide resulting would amount to 0·048 cubic foot. Except under very exceptional circumstances, ventilation would reduce these quantities in nearly the same ratio as the carbon dioxide, the total volume of sulphur dioxide due to the combustion of the gas being reduced to very minute traces. The presence of undue quantities of

sulphur dioxide in the air as the result of burning gas is chiefly productive of injury to health owing to the fact that by combining with the moisture and oxygen present in the atmosphere it becomes slowly converted into sulphuric acid. This contingency is likely to be of rare occurrence in inhabited rooms, as it cannot take place unless the percentage of water vapour present in the air be at saturation point, an event of most unlikely occurrence.

If we adopt, as is usual, the amount of carbon dioxide yielded as our measure of vitiation of the atmosphere, we find that each cubic foot of gas burnt per hour on an average vitiates as much air as would be rendered impure by the respiration of an individual for, as has already been stated, an adult exhales 0·6 cubic foot of carbon dioxide per hour, and 1 cubic foot of ordinary gas yields on combustion 0·52 cubic foot of carbon dioxide.

The relative amounts of oxygen removed from the air and carbon dioxide and water vapour yielded by various forms of artificial light in order to give an illumination equal to 16 candles, is given in the following table, in which is also incorporated the number of adults who would exhale the same amount of carbon dioxide in the same time:—

	Sperm candles.	Paraffin oil.	Gas burned in	
			Flat-flame burners.	Incandescent gas-lights.
Amount burnt	1740 grs.	992 grs.	5·5 c. ft.	3·0 c. ft.
Oxygen removed . .	9·63 c. ft.	6·24 c. ft.	6·50 c. ft.	3·8 c. ft.
Moisture produced . . .	6·56 c. ft.	3·50 c. ft.	7·35 c. ft.	4·6 c. ft.
Carbon dioxide produced .	6·56 c. ft.	4·45 c. ft.	3·50 c. ft.	2·0 c. ft.
Air vitiation equal to adults	11·0	7·5	5·0	3·0

If we know, therefore, the amount of impairment and vitiation of the atmosphere produced by one gas-burner, lamp, or candle, it is easy to arrive at the relative contaminating effect which the various artificial lights produce on the air of a dwelling-room. It follows, therefore, that a system of ventilation designed for a room when no artificial light is used, cannot be expected to be successful when a number of candles, lamps, or gas-jets are burning. Although the contaminations, especially in the case of gas, are very great, it is estimated that for their proper dilution the amount of fresh air supply in relation to the carbon dioxide evolved need not be so great in their case as for breath impurities, a supply of 900 cubic feet of fresh air for every cubic foot of

carbon dioxide per hour, evolved by the light, being deemed sufficient, and as every cubic foot of gas evolves 0·52 cubic foot of carbon dioxide, it results that, for every cubic foot of coal-gas burned, something like 450 cubic feet of fresh air should be supplied per hour in addition to those needed to dilute the respiratory impurities.

As judged by the rules already laid down that the vitiation of the air of any limited space, such as a room, is measurable by the heat and moisture and carbon dioxide generated, it appears that candles are most injurious to health and comfort, oil-lamps less so, and gas the least of all. Practical experience does not bear this out, since the discomfort and sense of oppression felt by the use of gas in rooms is much greater than that following the use of oil or candles. The explanation of this discrepancy between science and everyday life probably is that, in attempting to light a room with either candles or oil, we are content with much less intense, but a more localized, illumination than when we employ gas. Say we have a room 16 feet long, 12 feet wide, and 10 feet high, and requiring for proper illumination a light equal to at least 32 candle-power. In such a room, if using candles, we should in all likelihood be content with a couple of candles placed near us to read or work, and not place 32 candles in different places to give a diffused yet sufficient light. It is obvious that with only two or three candles we should have less air vitiation produced than if 32 were burning.

Illuminants not only yield actual impurities to the air, but also heat it. The amount of light evolved depends entirely upon the heat generated, simply because much of the light evolved is dependent upon the incandescence or excessive heating of the solid particles of carbon in the flame; and the greater the temperature to which these solid matters are raised the brighter the light. This is one of the reasons why gas is tested by its calorific value or in terms of thermal units.

The more recent improvements in gas-lighting have done much to lessen the vitiation of the air by the products of combustion in dwelling-houses: partly by ensuring a more complete combustion of the gas and partly by arrangements for the rapid removal of their engendered impurities. The former is secured by arranging the burners upon the principle of the Bunsen burner, in which, the gas being mixed with atmospheric air, the combustion is nearly perfect, and consequently no unburnt particles either of carbon or other matter escape unconsumed to foul the air. The incandescent gas-light as now in the market is based upon this principle, the light being derived from the incandescence or glow of a thin veil or mantle exposed to a Bunsen

flame. This light is very brilliant, economical in its consumption of gas, and hygienically sound; its practical defect is its great whiteness and dazzling illuminating power.

Acetylene has come into some prominence lately as an illuminant. It is derived from the interaction of water on calcium carbide. Compared with ordinary coal gas of 16 candle-power, acetylene shows an illuminating power of 240 candles. Although yielding a very brilliant light, the use of acetylene needs absolute soundness of gas-fittings inside the house, as an escape of this illuminant is liable to be accompanied by grave consequences. When inhaled it acts forcibly and injuriously on the respiratory functions of the hæmoglobin of the blood, and within the limits of 3 per cent. acetylene and 82 per cent. of air may lead to explosions.

Some municipalities and gas companies have taken up the use of so-called "water-gas." This is made by passing steam through incandescent coke or anthracite coal; it is further rendered luminous for lighting purposes by a process known as "carburetting," in which vaporized mineral oil is added to the gas. Carburetted water-gas has a distinct smell like that of coal-gas, and is usually highly charged with carbon monoxide, which may amount to as much as 35 per cent. The particular danger associated with the use of water-gas is that of poisoning by carbon monoxide, and necessitates the use of most accurately made gas-fittings. Dowson gas is a modified form of water-gas, and presents the same disabilities.

The most hygienic form of light which can be imagined is, of course, the electric incandescent lamp, which, other than giving out some heat, yields no impurities to the air. The arc electric light, which is unenclosed, is said to vitiate the air by the formation of nitric acid, but even if so, its effects in this direction are much less hurtful than gas, oil, or candles.

Quantity of Fresh Air needed.—Having now learnt something of the impurities poured into the air of our homes as the result of both respiration and artificial lighting, we have next to learn how much fresh air is required to dilute and remove those impurities, and how best this supply can be attained.

It has already been stated that an average adult exhales or gives off to the air 0·6 cubic foot of carbon dioxide per hour, and since anything below or just up to this amount of carbon dioxide in 1000 cubic feet of air in a room is indistinguishable by the sense of smell from the ordinary outer or pure atmosphere, that limit or amount of carbon dioxide can be regarded as the standard of efficient ventilation. But 1000 cubic feet of pure air contain 0·4 cubic foot of carbon dioxide, therefore they can take up or

receive 0·2 cubic foot more of carbon dioxide and not contain an excess over the standard limit of 0·6 cubic foot. The quantity of 0·2 cubic foot of carbon dioxide per 1000 of air, or 0·0002 per cubic foot of air, is commonly spoken of as the *standard permissible impurity*. Based upon these facts, the late Professor de Chaumont suggested a very simple formula to determine the volume of pure air requisite each hour to keep the carbon dioxide in the air of any inhabited room at this limit of 0·6 part per 1000 volumes.

Let **A** be the quantity of carbon dioxide given off per hour per head. Let **B** be the proposed permissible maximum quantity of carbon dioxide in the air of the room per 1000 cubic feet of air. Let **C** be the amount of carbon dioxide present in 1000 cubic feet of fresh air. Let **D** be the amount of fresh air required per head each hour to maintain the standard quantity B, expressed in thousands of cubic feet. Then $\frac{A}{B - C} = D$, or $\frac{0·6}{B - 0·4} = D$, and if we take B to be 0·6 cubic foot per 1000 of air, we get the formula to read thus: $\frac{0·6}{0·6 - 0·4} = D$, or $\frac{0·6}{0·2} = 3$ in *thousands* of cubic feet of air needed each hour per head.

If it be the case of an individual doing light work in a room, and giving off say 0·95 cubic foot of carbon dioxide per hour, we should have $A = 0·95$, and the formula stands as $\frac{0·95}{0·6 - 0·4} = D$, or, in other words, D would equal 4750 cubic feet of fresh air required hourly in order to keep the impurity down to the standard limit.

The formula can be used in another way. Suppose the air in a room has been found to contain 1·2 volume of carbon dioxide per 1000—that is, 0·0012 per cubic foot of air—and it is required to know how many cubic feet of fresh air have been hourly delivered per head. In this case, the actually observed air impurity, namely, 1·2, takes the place of the maximum permissible impurity; that is, B now equals 1·2, hence we get $\frac{A}{B - C} = D$, or $\frac{0·6}{1·2 - 0·4} = D$, or $\frac{0·6}{0·8} = D$. That is, 750 cubic feet of air have been actually delivered per hour in the room.

By a transposition of the same formula we can calculate the probable condition of the atmosphere of a room into which a given quantity of air has been or is being supplied. The formula would then stand thus: $\frac{A}{D} + C = B$. If in a room containing 5 persons, each giving off 0·6 cubic foot of CO_2 hourly, we assume

1500 or 1·5 thousand cubic feet of air to have been supplied per hour and to represent D, we get $\frac{5 \times 0{\cdot}6}{1{\cdot}5} + 0{\cdot}4 = B$, or $B = 2{\cdot}4$; that is, 2 parts of carbon dioxide per 1000 of air will be present in the air of the room over and above what is normally present in the outer air. In some cases, of course, A would not be represented by 0·6 cubic foot, as say, in the case of an adult man doing hard work; the amount of carbon dioxide given off by him per hour would be as much as 1·96, or nearly 2 cubic feet, and in the case of children, might be as low as 0·4 per hour. The general statement, however, of the formula remains the same.

A consideration of these facts indicates that if we wish to keep the air of our homes at the standard degree of purity, it should not contain more than 0·6 part of carbon dioxide in 1000, or 0·2 part in 1000 over the average in samples of ordinary air. Further, in order to keep the carbon dioxide below 0·6 part per 1000, it is necessary to change the atmosphere by supplying fresh air, and this, as worked out, means a supply of 3000 cubic feet of fresh air every hour for each person. The following table gives the amounts of carbon dioxide given off by various persons per hour under varying conditions, and, corresponding to them, the quantities of fresh air theoretically needed :—

	CO_2 given off per hour in cubic feet.	Fresh air needed hourly per head in cubic feet.
Adult male in very hard work	1·96	9800
,, ,, in light work	0·95	4750
,, ,, at rest	0·72	3600
Adult female at rest	0·60	3000
Children	0·40	2000
Average of a mixed community	0·60	3000

Carnelley, Haldane, and Anderson, basing their opinion not only upon the average presence of carbon dioxide in the air, but also upon the organic matter and number of micro-organisms, proposed that instead of taking 0·6 cubic foot of carbon dioxide per 1000 as the limit, that the standard should be 1·0 for dwellings and 1·3 for schools.

In mines as much as 6000 cubic feet per hour have been proposed to ensure maximum energy in those working below ground. In hospitals and for the sick generally, the maximum amount of fresh air ought to be at least one-fourth more than that allowed in health. If 3600 cubic feet per hour be accepted as a general average supply for health, we may admit the needs of the sick to be at least 4500 cubic feet per hour.

As regards the amount of fresh air required for animals, the

following table gives theoretical quantities of air as worked out by various observers :—

	Cubic feet per head per hour.	Cubic feet of space.
Cows	8000	1600
Calves	3000	600
Horses	8000	1600
Dogs	500	100
Pigs	3500	700
Cats	400	80

It is probable that these amounts are too small; at least 25 cubic feet per pound of body weight ought to be supplied, as, like human beings, all animals thrive best in well-ventilated places.

Cubic Air-Space required.—Though theoretical considerations may indicate that certain quantities of fresh air are needed per hour per head in order to maintain the atmosphere at a degree of sweetness compatible with health, yet when it comes to actual practice, certain difficulties are met with. Experience shows that under the ordinary climatic conditions of this country, the air of a room cannot be changed more than three times an hour without causing much inconvenience by draught. This means that if we are to have 3000 cubic feet of fresh air each hour, we must each have a cubic air-space of at least 1000 cubic feet. If it be less than this, say, 100 cubic feet of space, then in order to deliver 3000 cubic feet of air hourly, the renewal of air will have to be thirty times in that period of time, and this we know, owing to the formation of draughts, would be unbearable unless the incoming air be warmed. At 60° F. air, moving at the rate of two feet per second, is barely perceptible; at three feet it is more so; and above this it becomes a draught. At 70° F. the velocity of the air-current can be even greater without being noticed. The question arises, what then is the least amount of cubic space through which the standard quantity of fresh air can be passed without causing inconvenience from draught? By experiments made with the best mechanical means and artificial heat, Pettenkofer determined that in an air-space of 424 cubic feet, 2640 cubic feet of air could be drawn through in an hour without perceptible draught; this was equivalent to a change of air at the rate of six times an hour. But in ordinary circumstances, and without artificial methods of warming the incoming air, a renewal of air in a room at the rate of six times an hour in this climate could not be tolerated. In fact, a change of air three or four times an hour is about as much as can be borne, and

this brings us to an original air-space of close upon 1000 cubic feet. Whatever the amount of air required hourly per head, the cubic space per head should be in the proportion of one-third this amount. The moment we attempt to ventilate a small space, say 500 cubic feet, by ordinary or so-called natural means of ventilation, the difficulties arise not so much from the actual rate of movement of the general mass of air, as from the velocity with which the air enters at the openings and the nearness and relative position of these to the persons occupying the space. In order to supply 3000 cubic feet per hour, in each minute $\frac{3000}{60} = 50$ cubic feet must enter, and in each second $\frac{50}{60}$ $= 0{\cdot}83$ cubic foot. If the inlet opening be a square foot, the velocity of a current that would introduce 0·83 cubic foot would of course be 0·83 linear foot per second. Taking a room with 3000 cubic feet of air to be delivered per hour, and having an inlet or opening of 12 square inches, the rate of movement of the incoming air would be 10 feet per second, or nearly seven miles per hour; the room being so small, the rapid current of air could not be broken up, diffused, and mixed with the larger mass in the chamber sufficiently before striking its occupants and giving rise to a feeling of draught. If, of course, the room were just double the size, say 1000 cubic feet, or the apertures of inlet be enlarged, the movement would be less felt; but if the space be small, say 500 cubic feet, any enlargement of the inlets renders them altogether too large in proportion to be practically allowable.

Even with some artificial arrangements, experience goes to show that in small spaces the air becomes much more impure than in large ones; the reason being that in small spaces, even if large quantities of fresh air are being supplied, little uniform diffusion occurs, as owing to the frequent establishment of direct currents between inlets and outlets, large amounts of the fresh air escape without being made use of; also that in small spaces ventilation gets stopped much more readily than in larger ones, and if this occur, the ratio of increase of impurities is far greater in the small rooms than in the larger.

The amount of air-space which these theoretical considerations indicate ought at least to be given to each adult, appears to be not less than 1000 cubic feet, but this is undoubtedly much in excess of what most people are able to get. Excellent as is the standard laid down by de Chaumont, prolonged experience shows it to be practically impossible of attainment in this country under ordinary circumstances. We, therefore, are disposed to accept the standard limit suggested by Carnelley as being one most likely to meet ordinary conditions. If we take that as being a maximum of 1·0 cubic foot of carbon dioxide per 1000 cubic feet of air, we

get a permissible respiratory impurity of 0·6 in place of 0·2 cubic foot as suggested by de Chaumont. This means a need of 1000 cubic feet of fresh air each hour in place of 3000, and assuming that the necessary change of air cannot be made oftener than three times an hour, we find the minimum air-space for each adult will then stand at about 350 cubic feet; this we find to be closely in accord with present-day conditions. For humified weaving-sheds and workshops, the regulations of the Home Office permit a maximum of 9 volumes of carbon dioxide in 10,000 of air when no gas is burning. This means a permissible respiratory vitiation of 0·5 per 1000 of air. A departmental Committee, dealing with the same subject, went so far as to recommend an increase of permissible CO_2 to 12 volumes by day and 20 by night with gas burning, for every 10,000 volumes of air. We confess to grave doubts whether this reduction of ventilation standards in places of this kind is wise, though we are fully alive to the difficulties in the way of securing the lesser degrees of vitiation as laid down by earlier writers on the subject.

In the majority of rooms occupied by the poorest classes, the cubic space available for each occupant is rarely more than 250 cubic feet, while in the lodging houses of the larger towns the allowance is not more than 300 cubic feet. In elementary schools the regulation minimum allowance is 100 to 120 cubic feet per head. In factories and workshops, 250 cubic feet of air-space are required per head during the day, and 400 cubic feet during overtime. For soldiers in barracks, 600 cubic feet is the least space allowed. In hospitals, the cubic space ought to be quite 1500 cubic feet, if not nearly 2000; and the minimum floor-space 100 square feet. In all rooms with more than one occupant, it is necessary that a certain floor-space should be allotted to each person, for the purpose of allowing currents of air to remove emanations from one individual without interfering with his neighbour. For this reason, in all cases, whether private houses, barracks, hospitals, or other public buildings, a good rule is to secure as the lowest limit of floor-space an area not less than one-twelfth of the cubic space. Moreover, it is important to remember that mere height in a room is of no advantage unless combined with means for removing the heated air from the upper part, and that mere cubic space cannot take the place of change or renewal of air, for even the largest of air-spaces can only supply sufficient air for a limited time, after which the same amount of fresh air must be supplied. This 350 cubic feet of space for one adult would be sufficient if the air in it were changed three times an hour, but in the absence of any renewal, 350 cubic feet of air would only be sufficient for one person for 20 minutes. Of course, it must not be overlooked

that the source from which supplies of fresh air are drawn must be pure; and that, notwithstanding the fact of the standard quantity of air being delivered hourly per head, no claim could be made in such case for the existence of proper ventilation if the incoming volumes of air were in any way derived from contaminated or impure sources. In a similar way, attention needs to be directed to the actual temperature of the air entering a chamber; in summer it may need to be cooled as much as it requires to be warmed in winter, the reason being that the actual temperature of an air-current is the main factor in our appreciation of its velocity. Owing to the fact that expired or foul air is warmer and lighter than pure air, it tends to rise to the upper parts of a room, for which reason, to ensure free ventilation, the outlets for impure air should be at or near the highest point, and the inlets, arranged so as not only to avoid draughts blowing upon the occupants, but also to secure equal diffusion of the air, should all be given an upward direction, whereby the tendency of the fresh masses of air, particularly if cool, to fall to a lower level, is minimized as far as possible.

We have already defined ventilation as the removal or dilution, by a supply of pure air, of all the impurities which can collect in the air of inhabited rooms or houses. The next matter which demands consideration is how the ventilation of a room can be secured. It is usual to class the different methods of securing ventilation under two general heads: they are, the *natural* and the *artificial*. Now, all the methods of spontaneous diffusion produced by the unequal density of two columns of air, whether caused by chimney draughts or otherwise, belong to the former class; while the various methods of ventilation by means of pumps, fans, bellows, and various other contrivances, belong to the latter. The principles which bring about both these methods of ventilation are not difficult to understand, being based upon the action of well-known physical laws, all of which were discussed when we considered the physical properties of air.

Natural Ventilation.—This is carried on by the simple agency of gaseous diffusion, winds, and the movements of air caused by inequalities of temperature. We have seen that every gas diffuses at a rate which is inversely proportional to the square root of its density, and that while two gases of the same density show little tendency to mix, two other gases of different weights or densities would intermingle with great rapidity. For this reason, the air of rooms, being usually warmer than that outside, diffuses with rapidity through cracks and openings, and even through porous materials, such as sandstone, bricks, mortar, and mud. To such an extent is this the case that experiments have

shown that with a brick-and-mortar wall, a room containing 2700 cubic feet of air has its entire contents changed in an hour when the inside temperature is 65° F. and the outside just freezing. The amount of interchange between the inside and outside airs of rooms rapidly lessens, the more the temperature of the inside and outside agree one with the other; this explains why a room is often better ventilated in winter during a frost, with all its windows and doors shut and with a good fire in the grate, than in summer, with the windows wide open, and the inside and outside temperatures nearly identical. As a ventilating power, diffusion alone is found to be inadequate.

The action of winds, as an agent in the production of natural ventilation, is partly by what is called perflation, and partly by aspiration. The wind is said to perflate if it pass freely through open doors and windows into a room; its ventilating action then is immense, but much less so if a thorough current cannot be obtained, as in narrow courts and alleys, or when pieces of furniture, curtains, etc., block the way. Mention has already been made of the ease with which air can pass through bricks, etc., but the action of the wind in this respect is probably not so powerful as generally believed. The ventilating power of winds by mere perflation is irregular, owing to the uncertainty of the air movements.

As illustrating the great aspirating power of the winds, as a ventilating agent, we may refer to the fact that winds blowing over the tops of chimneys or tubes cause a current of air to flow at right angles to themselves up the chimney or tube (Fig. 3); at the same time a similar wind can and does impede ventilation by either blowing against some opening or down a chimney. This reverse action can, of course, be obviated by placing a cowl or other similar contrivance on the top of the chimney. Many schemes of ventilation fail owing to their having been designed with too little regard to the diversities of wind force and direction.

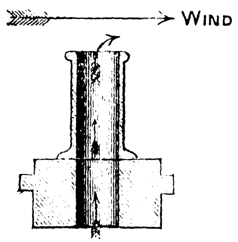

FIG. 3.—Draught up the chimney caused by the wind blowing over the top.

The primary force, which produces not only winds but the movement of all bodies of air, is the difference in their weights or densities due to inequalities of temperature. If a column of air contained in a tube or chimney be heated, it expands, and the movements of this expanded air depend upon the following considerations: (1) Upon the difference between the temperature of the inside and outside airs. (2) Upon the area and other condi-

tions of the openings through which warmed air can flow out and the cooler air flow in. (3) Upon the height of the ascending column of warm air.

If a column of air, say in a chimney, be 10 feet high, and have its temperature raised by a fire in the grate below, 20° F. above that of the air outside the chimney, then it will expand, for reasons already explained, $\frac{20}{491}$, or as near as possible $\frac{1}{24}$ of its bulk; as a result its specific gravity or density would be lessened, and it would require to be $10\frac{10}{24}$ feet or 10 feet 5 inches high to balance a column of the outer air 10 feet high when the temperature of the latter is 20° F. lower than the former; but as the height of the warmer column is exactly that of its containing chimney, which is only 10 feet high, the colder or outer column of air presses it up with a force proportionate to their difference in weight, and with a velocity equal to that which would be acquired by a body falling through a space equal to the difference in height that the two columns would occupy, if of equal weight, which in this case is 5 inches or 0·4 foot.

Now, by an application of the combined laws of gravity and the acceleration of forces, we are able to express the velocity in feet per second of a falling body by the formula $V = \sqrt{2gh}$, in which g is the velocity given to a falling body by the accelerative force of the earth's gravity; this, in our latitude, is 32·2 feet per second; h is the height through which the body falls. This formula, $V = \sqrt{2gh}$, which is sometimes called Montgolfier's formula, will then stand or read, $V = \sqrt{2 \times 32{\cdot}2 \times h}$; but that portion of the formula $\sqrt{2 \times 32{\cdot}2}$ equals 8·02, or practically 8. Hence, we can simplify it and write $V = 8\sqrt{h}$, or say the velocity of the falling body equals eight times the square root of the height it falls. In the case we have supposed, 0·4 foot is the height of the effective descent or fall of the heavy column of colder air; hence, applying Montgolfier's formula, we can say $8\sqrt{0{\cdot}4} = 5{\cdot}056$ feet per second, or 303 feet per minute, will be the velocity with which the heated column of air would be drawn up the chimney. Very often in its application to ventilation problems the whole calculation is expressed by the formula being written thus—

$$V = \sqrt{2ga(t' - t)h},$$

in which the other symbols remaining as above, a is the coefficient of the expansion of air for each degree of temperature, t' the temperature of the heated column of air, and t that of the colder.

Having ascertained the exact velocity of the air-current, this, multiplied by the area of inlet, gives the cubical amount entering

the space. Supposing, in the above example, the opening or throat of the chimney were one foot square, there would pass out or up that chimney 303 cubic feet per minute. This rate of flow is, however, subject to certain corrections, chiefly in consequence of friction arising from angular deviations of the chimney or tube. In straight tubes, the friction is found to be in all cases directly as the length of the tube and inversely as the diameter. In general practice, a deduction of from one-fourth to one-third of the velocity is necessary to compensate for these influences, and to obtain a true rate of outflow.

There are various other ways of determining the direction and velocities of air-currents. Thus, by noting the direction of smoke caused by burning pieces of velvet; by floating hydrogen balloons so weighted as to be of the same specific gravity as the air; or, if such be available, by means of an anemometer. This latter is a very delicate instrument, consisting of four vanes attached to a spindle, the revolutions of which are recorded on a dial. If placed in an air-opening about $\frac{2}{3}$ of the diameter from the side, so as to obtain the mean velocity, the vanes are turned by the direct action of the air-current, and the velocity calculated from the linear movement as recorded on the dial-plate during some given period of time; this, multiplied by the sectional area of the opening, gives the cubical delivery or discharge according as to whether it be an inlet or an outlet. The actual velocity of air as it flows in and out of a room should not exceed one or at most two feet per second, simply because a low velocity is favourable to uniform diffusion of any incoming air through the room, and because a high velocity is apt to give the sensation of a draught. As explained, some allowance must be made for friction, particularly in outlets, and here the velocity should not exceed 3 to 5 feet per second. The particular velocity in any given case will naturally be regulated by the sizes given to the inlets and outlets, and on the quantity of air needed as indicated by the precise number of occupants, the amount of artificial lighting, and other special causes of air vitiation.

Having in the preceding pages learned something of the general laws and circumstances which govern the movements of air, as well as considered the amount of air to be provided, it is necessary now to discuss the various methods which have been adopted or proposed to practically apply them. Of all the methods of natural ventilation, the simplest and most obvious is that of more or less open doors and windows; but this arrangement, except in the warmest summer weather, causes draughts, and is unpleasant. To secure adequate perflation, all windows should, if possible, be placed on opposite sides of a room, while,

too, each of such windows should be made to open at the top. Owing to air flowing against the body, at or even slightly above the temperature of a room, causing a sensation of cold or draught, it is necessary for comfort that air should be introduced and removed from inhabited rooms at those parts where it will not give rise to a sensible draught. In a large majority of houses, particularly those of the poorer and middle classes, even in these days, ventilation arrangements are either of the most crude and haphazard kind, or else absolutely wanting altogether. The greater number of living-rooms depend for their supply of fresh air upon just so much as can find its way in through doors, windows, or through cracks and crevices around and under doors and windows, or even through the floor, and for the escape of foul air, upon what goes up the chimney, if a fire be alight, or what can get out through doors and windows; the general result being that either the chamber is so cold and draughty that no one can live comfortably in it, or so hot, close, and stuffy, that health is affected.

All ventilation methods aim at avoiding these results, by providing, in the first place, inlets, or means of entrance for the fresh air, and outlets, or means of escape for the foul or impure air. It will be readily understood that all *inlets* or orifices by which cold fresh air is admitted should be above the level of the heads of those occupying a room, say 9 feet, and directed upwards to the ceiling, while the actual current itself should be as much broken up or dispersed as possible by means of trumpet-shaped openings, the smaller apertures of which are towards the outer air and the wider towards the room. If the inlets be intended for delivering previously warmed air, then they should discharge near the floor. The warming of air previous to its entering a room by an inlet is conveniently done, either by the use of an air-chamber placed behind a grate or stove, as in Galton's stove, or by the passage of it over hot-water pipes.

As to *outlets*, since the escaping impure air is invariably warmer than the incoming or fresh supply, the right place for them is the top of the room, and in cases where the foul air is specially warmed, as over ventilating gaslights, the connection of the outlet tube with the chimney constitutes the best arrangement. In all cases, these structural devices, whether as inlets or outlets, should permit of their being kept free from dirt or otherwise getting blocked up.

Among the many devices for inlets of fresh air is the simple plan, suggested by Hinckes Bird, of raising the lower sash of a window by an accurately fitting block of wood, whereby a corresponding space is left between the meeting-rails in the middle of

the window, through which entering currents of fresh air are directed up towards the ceiling (Fig. 4). With the same idea, others have proposed double panes of glass, an open space being left at the bottom of the outer and at the top of the inner one. Similarly, a pane may be louvred, that is, strips of glass lying one over the other, and fixed on to a frame, which, by means of a

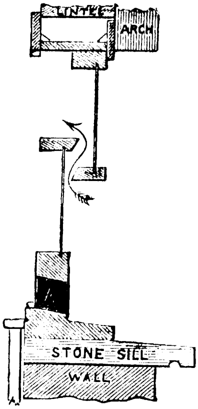

FIG. 4.—Hinckes Bird's plan of window ventilation.

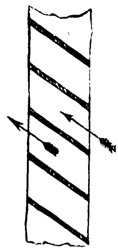

FIG. 5.—Louvre ventilator.

lever, can be opened or shut at will (Fig. 5). Windows can be so made that, when they open, they slope into the room, or they can have a part of a pane to open or shut by a spring, as in Boyle's or Cooper's ventilator (Fig. 6).

An excellent form of inlet is that known as Sherringham's

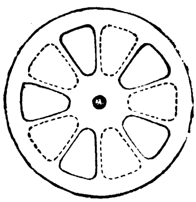

FIG. 6.—Cooper's ventilator.

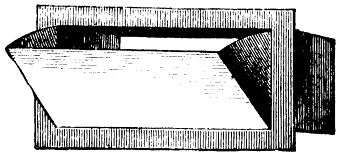

FIG. 7.—Sherringham valve.

valve (Fig. 7), which consists of an iron box so made that the air enters from outside through a perforated brick or grating, and is directed up towards the ceiling by means of a valve which can be made to close or open by means of a balanced weight. The inside area of the ventilator is larger than the outer, consequently

the air enters the room at a less velocity than at which it passed through the outer wall or grating. Another plan, advocated originally by Tobin of Leeds, is that of introducing the air through horizontal shafts under the floor, and then delivering it into the room through vertical tubes (Fig. 8), at different heights, varying from 6 to 9 feet from the floor. The currents of air issuing from these tubes ascend and then curve imperceptibly downwards. For public buildings, like churches or halls, the columns which support galleries may on this principle form convenient inlet tubes. These Tobin tubes are not very suitable for ordinary houses and dwelling-rooms, as they are difficult to keep clean, and often become clogged up by cobwebs, dirt, and dust. They, moreover, do not readily become or act as outlets when occasion requires, which, being a conspicuous feature of the Sherringham valve, renders that form of ventilating agent practically the most convenient for everyday application.

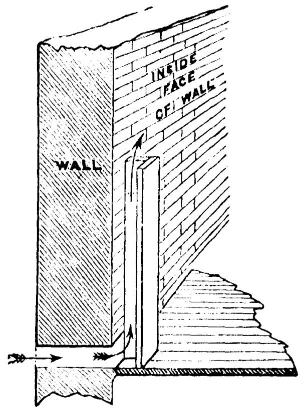

FIG. 8.—Tobin's ventilating system.

Suitable inlets can be provided by what are known as air-bricks, of which probably the best types are those of Ellison and of Jennings. They are merely specially prepared bricks perforated with a number of holes, so cut that the inner aspects of the perforations have a larger diameter than the outer, whereby the velocity of the entering air-current is lessened. The wind blows through them, but with a variable movement. In Jennings' air-brick, the perforations are directed upwards, so that the entering air-current flows rather towards the ceiling than down towards the floor.

With all or any of these simple ways of letting fresh air into rooms, it is presumed that equal facilities are offered for the escape of the foul air. In most rooms, particularly if a fire be alight, this will be done largely by means of the chimney connected with it, but in its absence may need be accomplished by special outlets. The simplest form of outlet, other than a chimney, is a special shaft from the ceiling to above the roof; this is the principle adopted in the army for ventilating barrack-rooms and hospitals, combined with arrangements for admitting warmed air. The movement of air up such an outlet shaft will largely depend upon the aspirating action of the wind over its top, and upon the

particular temperature inside it as compared with that of the outer air. Owing to the uncertain and disturbing action of these influences, these shafts do not always act as outlets, but in any case facilitate a continuous change of air, whichever way they happen to act. Down currents in such shafts can usually be obviated by placing a cowl or valve on its upper orifice, or by leading it up inside a chimney.

Frequently so-called ventilating gaslights are used as outlets, in which the products of combustion, after being collected by means of a cover or bell-glass, are carried off by a tube which is itself often contained in a larger one. Owing to the heating of the inner tube, the space surrounding it and between it and the outer one acts as an extracting-shaft for foul air. In theatres and other public buildings, advantage is taken of this method by using the Sunlight gas-burners, which, in addition to lighting the building, act as extraction-shafts for removing the polluted air.

Another arrangement, known as Arnott's valve (Fig. 9), is designed to act as an outlet for foul air. It is usually placed in the wall of a room near the ceiling, so as to open into the chimney. The valve is so arranged as to swing towards the chimney, when the pressure or draught of the air is from the room to the chimney; but when the pressure is greater from the chimney to the room the valve closes, and thus prevents the escape of smoke or air from the chimney into the room. These valves are sometimes objectionable owing to the noise they make.

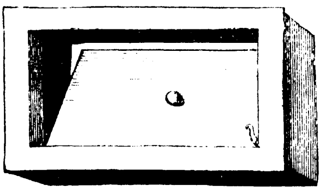

FIG. 9.—Arnott's valve.

An ingenious ventilator is that of McKinnell's, which consists of two tubes, one inside the other, carried up through the ceiling of a room; fresh air passes down in between the two tubes, and by a flange on the inner tube is dispersed. The inner, or outlet tube, which is always made sufficiently large to equal in area the inlet, projects well beyond the other, both above and below, and effectively carries off foul or impure air. This is a very useful method of ventilation under certain conditions, but, like all others, is not universally applicable. On much the same principle, ventilating cornices are made, which consist of a double channel of perforated metal: by the lower channel cold fresh air is brought into a room, while by the upper one the fouled air is carried to the chimney or other outlet. Analogous to this plan is that of carrying along the cornice of a room, on

three sides, a perforated inlet tube, while on the fourth side is a similarly perforated outlet tube.

In other cases, by a like contrivance a fairly good cross-ventilation can be secured by means of a series of transverse ventilating boxes or tubes placed at regular intervals and close to the ceiling. These, running across the room from wall to wall, open into the outer air at each end by an air-brick. The sides of these tubes are made of perforated zinc, and to prevent the wind blowing right through, they are stopped or blocked in the centre by a partition. According as to whether the wind blows from one side or other, so one half becomes an inlet for fresh air, which diffuses gently into the room through the perforations, while the other half acts as an outlet for the fouled air.

As regards the size of inlets and outlets, the conditions of temperature are so variable that it would be impossible to fix on a size that should be universally applicable; as an average for this country a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt. As a rule, the size of these openings should be in proportion to the size of the room; it is better to have openings too small than too large, and while the inlets and outlets can be usually of the same size, still no one individual inlet ought to be larger in area than 60 square inches, nor an outlet more than 144 square inches.

Artificial Ventilation.—For the production of artificial ventilation, two systems are in use: namely, ventilation by extraction and ventilation by propulsion.

The simplest example of ventilation by *extraction* is the action of an ordinary fireplace, which, by heating a column of air, causes its expansion, ascent, and replacement by another but colder volume. The ventilation of theatres is largely carried out by utilizing the central chandelier and all the gas-jets, which being each placed under outlet tubes, by warming the vitiated air, cause it to expand and escape up the tubes, which are so arranged as to all unite and empty themselves into a single large outlet, thus serving to carry off the products of both respiration and combustion. Mines are largely ventilated by means of a furnace at the foot of the upcast shaft, its supply of air being drawn down another shaft and then made to pass through all the workings on its way to the upcast by an ingenious arrangement of doors and partitions.

As typical of an elaborate means for ventilating artificially a

large building may be mentioned the system employed in the House of Commons. The system is a plenum one, coupled with exhaust, a condition of working being that the inflow of air is slightly in excess of that extracted. There are three air intakes at the basement. At the initial point of entry the air passes over heat radiators; these are for use during cold weather. The air is drawn through wire screens, 20 meshes to the linear inch, in front of which are water sprays. The effect of this screen is to remove 60 per cent. of the suspended bacteria, increase the humidity, wash out any fog, and give a

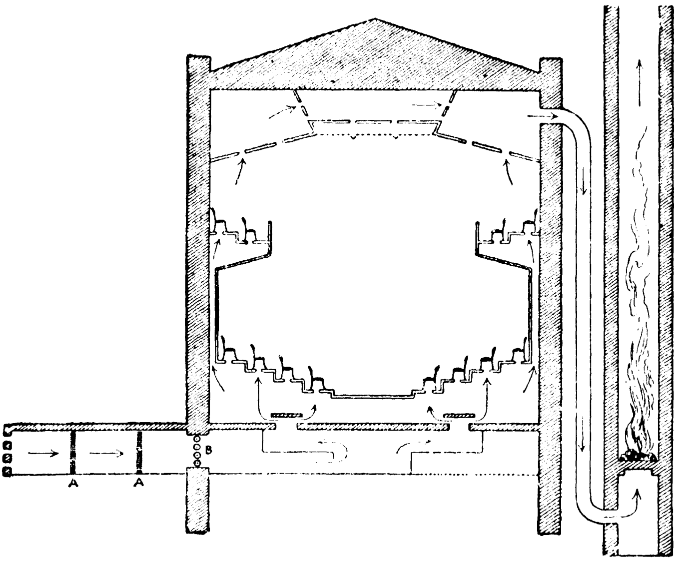

FIG. 10—Diagram of ventilating the Houses of Parliament.

definite cooling effect. The air supply then passes along a glazed duct to the input fan, running at from 100 to 190 revolutions per minute, and giving in that time from 20 to 60 thousand cubic feet of air. Between the fan and water screen are special chambers or air locks to prevent side leakage of undesirable air from the basement corridors. From the fan the air passes along another duct to a heating chamber, fitted with radiators. In time of fog, the direct connection between the fan and the heating chamber is closed and the air diverted so as to pass through a huge cotton-wool screen which acts as a filter and removes the suspended

material of which a fog consists. In fog time, after being so filtered, the air passes to the heating chamber. Between this heating chamber and the debating chamber is an equalizing chamber where the air is made equable in velocity and temperature.

The control of the whole system is from this point. From the equalizing chamber the air enters the debating chamber by the perforated gangway floors and by apertures beneath the benches. The vitiated air is extracted from the debating chamber through apertures in the wall panels by means of an outflow fan, similar to the input fan. The extracted air is discharged into a vertical shaft fitted with a furnace. The outflow fan is connected also by ducts and shutter valves with the lobbies, and can, if necessary, extract wholly from these places. This is a flexible arrangement whereby the whole system can be varied according to where the members of the House happen to be. In addition, there are 64 sun gas-burners in the debating chamber, the draught from them being sufficient to renew the contents of the chamber once an hour. The ventilation of the gallery is on the same principle, controlled by a separate series of ducts and a separate outflow fan.

In dwelling houses it has been proposed to have a central chimney, into which the flues of all the fires shall open, and to surround this with air-shafts from each room. It is supposed that, if other inlets exist, there will be a current both up the chimney and up the shaft running beside it. In all these cases it is necessary that the workmanship be very exact, so that air shall not reach the extracting shaft except through the tubes.

On board steamships, a similar plan is arranged, the upcast being a space round the boilers and funnel; and while a strong current of air rushes up this space, air to feed it is directed down the hatchways. The same method is turned to account in hotels and public buildings by the utilization of hot-water pipes to cause currents of air in suitable extraction-shafts.

As aids to extraction methods, various forms of cowls have been invented, but no one of them can be recommended as being absolutely successful. More successful is extraction by fans. A paddle-wheel-shaped fan, inclosed in a chamber, is placed in the roof of a building and conveniently driven by a small engine. By the revolutions of the fan, the foul air is drawn up from the apartments through ventilators placed near the ceiling into tubes, and by them conducted to an open-air outlet above the fan. Fresh-air inlets are of course provided near the floor levels of the room so ventilated.

In the case of ventilation by *propulsion*, the air is driven mechanically by either bellows, pumps, or fans into proper

channels. This plan of artificial ventilation is more adapted for factories and workshops than for ordinary houses. In the former, besides for ordinary ventilation, currents of air are often required to blow away dust or suspended matters, for which purpose the openings need to be near the floor and not near the ceilings, as for ordinary vitiated air. Strictly speaking, what is called the propulsion method is an impulsion system, as by it fans are used to propel air into a basement chamber, from whence, after being heated over coils of hot-water pipes, it is carried by ducts to each room separately. These ducts open some 7 feet above the floor level, and as the velocity of the impelled air is considerable, it is diffused near the ceiling, and moves down through the room imperceptibly, to finally escape at the floor into vertical outlet shafts discharging at the roof.

Though much less common than extraction methods, ventilation by propulsion has the advantage of precision and ease and certainty with which any given volume or required volume of air can be treated or used; it, however, is expensive. Owing to the absence of control over the sources from which air is sucked in extraction methods, due to the readiness with which air rushes in at all available apertures, the supplies of air under these circumstances are occasionally drawn from objectionable places. With care, however, provision can be made to either warm, cool, wash, or filter the air at suitable points.

On the whole, the advantages of artificial ventilation are great, being mainly due to its facility of management and constancy under varying conditions. For factories, workshops, ships, and wherever there is machinery, artificial ventilation, whether by extraction or propulsion, is certainly the most economical and convenient. On the other hand, public buildings, such as prisons, theatres, and hotels, commonly require to be ventilated by some mechanical arrangement based upon the utilization of all fires and gas to work an exhaust-shaft. In private houses, the use of ventilating grates and stoves, or some of the simpler plans of ventilation, should suffice to keep the air pure, but no hard-and-fast rule can be laid down, each case requiring to be considered intelligently on its merits.

Warming and Heating.

This subject is very closely connected with ventilation, but for its thorough comprehension some knowledge is necessary of the laws of heat. Now, heat is distributed in three ways: these are by radiation, by conduction, and by convection.

Radiation of heat is not only the most common but the most

wasteful. This kind of heat is propagated in straight lines in all directions with equal intensity, the effect lessening according to the square of the distance; thus, if the heat at one foot distance from a fire be 1, then at ten feet it will be one hundred times less. If radiant heat fall on a solid body, it is reflected in the same way as light, but some of the heat is absorbed, the amount reflected and absorbed being in inverse proportion to one another, and largely dependent upon the surface, colour, and nature of the body.

Heat is conducted through all solids, but to a very limited degree only by liquids and gases. The best heat conductors are the metals, then stone, next wood, and least of all wool or silk. Bodies which are good conductors rapidly give off their heat to the surrounding air or to anything in contact with them; in like manner, if colder, they withdraw heat from other bodies. Porous materials, like felt, are extremely bad conductors of heat.

The **convection** of heat is that mode in which heat is propagated in liquids and gases, and is dependent upon that characteristic of those bodies which allows the portions of them which have been heated to expand and rise, their place being taken at once by colder parts. A sort of circulation of the water or air is set up, and the whole mass soon warmed.

Disregarding any particular variations in the source of heat, that is, whether from coal, coke, wood, etc., we can say that the principal methods of warming and heating houses or rooms may be classed as either open fires, closed fires or stoves, and pipes containing either heated air, hot water, or steam.

Open Fires.—Long-established custom and prejudice have caused open fires to be the means of heating nine-tenths of the houses in England, notwithstanding the fact that they are really the most costly and imperfect means of heating, as evidenced by the fact that they only render available 13 per cent. of the total heat capable of being yielded by coal or coke, and only 6 per cent. of that by wood, the rest being lost in the air, or escaping as unconsumed carbon up the chimney. The actual heating effect of open grates is most unequal in different parts of a room, but on account of the cheerful light which they emit, and the ventilation which they ensure, open fires will always be preferred as the pleasantest and healthiest mode of heating. Following Teale, the chief practical points to be aimed at in making open fireplaces, may be summarized as follows:—(1) Use as little iron, but as much fire-brick, as possible. (2) The back and sides should be made of fire-brick. (3) The back of the fireplace should lean or hang over the fire, while the throat of the chimney should be contracted. (4) The bottom of the fire

should be deep, and placed low down near the floor. (5) All slits in the bottom of the fire should be as narrow as possible. (6) The bars in front should be narrow. (7) The space beneath the fire should be closed in front by a close-fitting iron shield or "economizer." The object of this latter point is to secure as complete combustion as possible of the fuel at the bottom of the fire by the exclusion of cold air. In the use of an ordinary open fireplace, about one-eighth of the heat given off by the fuel consumed is utilized on the air of the room. All open grates should be made so as to have the fuel slowly and completely consumed, while the draught up the chimney should not be in excess of ventilation requirements. Most English grates consume 8 lbs. of coal in an hour: for the combustion of each pound of coal 300 cubic feet of air are needed; this means 2400 cubic feet hourly, but in actual practice something like 20,000, or even 40,000, cubic feet of air pass up the chimney; in which case, supposing the room contains 4000 cubic feet of space, the air in it gets changed from 5 to 10 times in the hour according to the strength of the fire. If the incoming air were warm, this liberal ventilation would be excellent; but, unfortunately, it rarely is so, but is in the main quite cold, finding entrance through the floor, or by chinks round the windows or beneath the door.

Stoves, as usually made, are of cast iron, and are essentially apparatus for heating with a detached fire, so placed that the products of combustion escape by an iron flue or chimney to the outer air, while the main portion of the generated heat radiates in all directions round the stove. At the lower part is usually a draught-hole, by which the air necessary for combustion enters. Owing to the less waste of heat by these means of warming than by open grates, this mode of heating is the more economical, but by no means so healthy as that by ordinary fireplaces, because their ventilating power is so much less. Stoves are often objectionable owing to their making the air hot and dry, but this can be obviated usually by placing vessels of water upon them. They often, too, emit a bad smell, due generally to the decomposition of organic matter present in the air, by contact with the heated sides of the stove and chimneys, or occasionally from the diffusion of carbon monoxide and other gases through the heated sides of the stove. These objections can in great measure be obviated by the use of wrought iron, and having the joints more securely riveted than is commonly the case; or the stoves may be lined with fire-brick and covered with tiles, as is seen in the better class of houses on the Continent.

Gas, of later years, has come into very general use both for

warming and cooking; it is admirably adapted for the latter, being not only cleanly but economical. For heating purposes, it has not made the progress which its many advantages deserve, probably owing to defective forms of stove used. Speaking generally, there may be said to be three common forms of gas-stove in general use: there are (1) reflector stoves, (2) condensing stoves, (3) asbestos or hollow-ball refractory fuel stoves.

The *Reflector stove* has usually a naked gas-flame, backed by a glass or metal reflector. It is bright and cheerful-looking, but gives out little heat, and unless provided with a flue—which more often than not is not provided—very considerably adds to the vitiation of the air.

Condensing stoves are those so constructed that the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and then caught in a tray beneath. This condensed vapour naturally carries down with it some if not all the sulphur products, but fails to remove any of the carbon dioxide which, notwithstanding all statements to the contrary, really escapes into the room. For this reason, this stove always requires a flue; unfortunately, its heating powers are small.

Stoves fitted with *asbestos fibre* or refractory hollow-ball fuel, and lighted by Bunsen or Argand burners, are relatively popular, owing to the fact that the fuel is rendered incandescent, with a close resemblance to the glow of an ordinary coal fire. These stoves yield radiant heat only as a rule, though a few are made with attached hot-air chambers, to give off heated currents of air. These are in the main good stoves, but somewhat extravagant as gas consumers, and always needing a flue to carry off products of combustion, and which as well takes off much of the heat which they produce as so much waste.

A notable improvement upon the various types of gas stove is the gas radiator, in which the intense heat from a Kern flame is translated into radiant heat by surrounding it with a perforated fire-clay tube. The whole radiator consists of a number of these tubes placed over Kern burners, each consuming two cubic feet of gas per hour. The Kern burner is a modified Bunsen. Experiments made with radiators of this type show that they give a cheerful, healthy, radiant heat combined with economical consumption of gas, and little or no deterioration of the air. Possibly, as electricity comes into more general use, a more extended employment of electric radiators for heating purposes will be a feature of many houses. On sanitary grounds, electric radiators are much to be recommended, as they emit heat without adding to the atmosphere any of the ordinary products of combustion.

Oil Stoves.—Under some circumstances the use of oil stoves affords a convenient means of heating rooms. Provided that the combustion of the oil is complete, and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil stoves for heating purposes may be advantageously employed. Their efficiency is increased by placing over them a diffuser or radiator, so as to distribute the heated products; care needs also to be taken that only the better kinds of mineral oil are used.

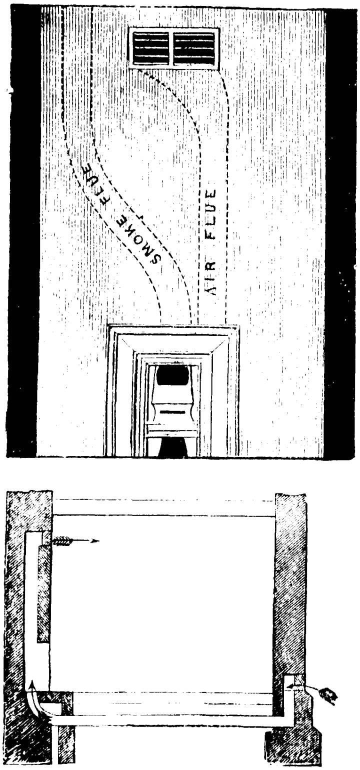

FIG. 11.—Elevation of Sir Douglas Galton's grate, and section of room, showing air-duct and flues.

Hot Air, obtained by driving air over hot bricks or pipes, is occasionally introduced into rooms and public buildings for heating purposes, by means of mechanical arrangements such as fans, as used in artificial ventilation methods. This is very efficient as a way of combining warming with ventilation, but is very costly. A modified application of this method was designed by Sir Douglas Galton in the form of a stove, in which the fire which warms the room is also utilized to supply warm air. The figure shows the existence of an air-chamber behind the grate, in which the air is warmed by the iron back, upon which several broad iron flanges are cast so as to obtain a large surface of metal to give off heat. The fresh air is obtained by means of an inlet flue from the outside, and, after being warmed, is passed into the room near the ceiling by the opening shown in the illustration. These stoves are in use in the British army for warming and ventilating barrack-rooms and hospital wards.

The chief objection to the use of hot air as a general means of warming a room or dwelling lies in the fact that heated air

is often unpleasantly dry, and when so employed should be moistened, or, if need be, purified by either filtration or washing.

Steam or Hot Water is closely allied to hot air for warming purposes. The ease with which all parts of a building can be heated by pipes containing steam or hot water is obvious, and, as applied to the needs of hotels, hospitals, churches, etc., is practically supplanting all other methods of warming. In the present day, steam is very little used for this purpose, since water, at either high or low pressure, is so much more convenient and cheaper. In low-pressure water systems the pipes are about 4 inches in diameter, and are always in a double row to allow of the water circulating. The boiler in connection with it is commonly placed in the basement of the building, and from its upper part runs a main pipe, ending in branches, which extend to the furthest end of the building; these then return underneath the others, unite into another single pipe, and then re-enter the boiler at its bottom. The circulation of the water is dependent upon the water, after being heated, being lighter than when cold, and as such tending to rise to a higher level; this having given up its heat to the various rooms, returns cooled by the lower pipe. The heat of the pipes is controlled by a valve which can be opened and closed at will. A feed-pipe from a supply cistern enters the return pipe near the boiler, while an escape for air is provided at the highest point of the system. In the high-pressure system, such as Perkins's, water is heated to about 300° F., in a portion of the pipes which pass through the furnace. This system secures a greater heat, but requires very careful management, as any failure in the circulation would at once result in an explosion. Under the low-pressure system, 5 feet of a 4-inch pipe will warm 1000 cubic feet of air from 32° F. to 55°, and 12 feet will warm the same to 65°; but under the high-pressure, in which the heating power is something like two-thirds more, a proportionately less length of piping is required.

For calculating the necessary radiation for any given house or building, the construction of such building must be considered as to the kind of outside walls, their thickness and material. So, too, the height of rooms will make a difference, while the ventilation must be also taken into consideration, and provision made to renew the air at least once an hour. The following general rules are given by Lawler:—

1. Allow 1 square foot of direct *steam* radiation for each 3 square feet of glass.

2. Allow 1 square foot of direct *steam* radiation for each 30 square feet of exposed or outer wall.

3. Allow 1 square foot of direct *steam* radiation for each 100 feet of space or contents of room.

It requires more radiating surface for hot-water heating than is necessary with steam, for the reason that the average temperature carried in a hot-water system is much lower than in a steam system. In round numbers, it requires about 25 per cent. more radiation surface for hot water than for steam. Lawler gives the following general rules :—

1. Allow 1 square foot of direct *hot-water* radiation to 2 square feet of glass.

2. Allow 1 square foot of direct *hot-water* radiation to 25 square feet of exposed wall.

3. Allow 1 square foot of direct *hot-water* radiation for each 75 cubic feet of air-space.

The Practical Examination of Air and Ventilation.

It has already been pointed out that the simplest test as to whether the ventilation of a room or a house is sufficient or not, is that of entering it from the external air, and noting the difference between the indoor air and the outside atmosphere in point of freshness. This test, however, only gives approximate results, and, in cases where more exactness is required, a more detailed examination is necessary. This, in every case, may be conveniently made to include the following points :—

1. The actual amount of cubic space, the relative size and position of inlets and outlets, and the amount of fresh air supplied.
2. The chemical examination of the contained air for impurities.
3. The nature of the suspended impurities.
4. Facts concerning the temperature and moistness of the air.

The determination of the actual amount of cubic space is merely a simple matter of measuring and calculation, combined with the making of certain deductions for bedding, furniture, etc., and irregularities in the shape of the space to be examined or additions for the cubic contents of open recesses. For each bedstead and bedding a general allowance of 10 cubic feet is made, and for the body of each adult 3 cubic feet. If the room be rectangular or regular in shape, its cubical contents will be obtained by multiplying together the three dimensions of height, length, and breadth; if the space be irregular in shape, with either rectilinear or curved lines, it is usually most convenient to divide it up into simple parts, such as either triangles or circles, as the case may be, and calculate the cubical contents by one or more

of the following rules. It is generally more convenient, too, to make the measurements in feet and decimals of a foot, than in feet and inches. If square inches are used, they may be turned into square feet by multiplying by 0·007.

Area of a circle = square of the circumference × 0·0796 or square of the diameter × 0·7854.
Circumference of a circle = diameter × 3·1416.
Diameter of a circle = circumference × 0·3183.
Area of an ellipse = the product of the long and short diameters × 0·7854.
Area of a square = the square of one of the sides.
Area of a rectangle = the product of two adjacent sides.
Area of a triangle = altitude × $\frac{1}{2}$ base, or base × $\frac{1}{2}$ altitude.
Area of any figure bounded by straight lines = divide it into triangles and take the sum of their areas.
Area of the segment of a circle = ($\frac{2}{3}$ × chord × height) $+ \frac{\text{cube of altitude}}{2 \times \text{chord}}$.
Cubic capacity of a solid triangle = area of a triangle × altitude.
Cubic capacity of a cylinder = area of base × altitude.
Cubic capacity of a cone or pyramid = area of base × $\frac{1}{3}$ altitude.
Cubic capacity of a dome = area of base × $\frac{2}{3}$ altitude.
Cubic capacity of a sphere = cube of diameter × 0·5236.

Thus, supposing it were required to determine the cubic capacity of a room 10 feet in height, and whose floor and ceiling shape were as drawn in Fig. 12, ABGCD. By dividing it into triangles and the segment of a circle, and then measuring the length of the various dotted lines, its total cubical capacity would readily be obtained. Assuming AB to be 6 feet, BC to be 8 feet, CD to be 6 feet, BD to be 10 feet, BE to be 7 feet, ED to be 3 feet, FD to be 9 feet, FA to be 4 feet, EC to be 4 feet, GH to be 3 feet, and BF to be 5 feet, we get the cubical capacity of each of the figures to be as follows:—

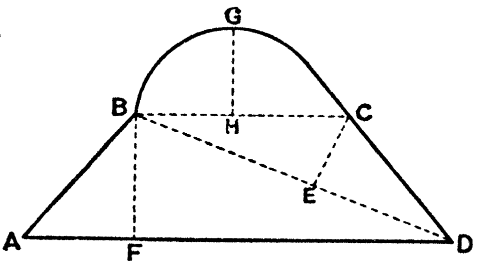

FIG. 12.

		Cubic feet.
ABF . . .	$4 \times \frac{5}{2} \times 10$	$= 100$
FBD . . .	$9 \times \frac{5}{2} \times 10$	$= 225$
BEC . . .	$7 \times \frac{4}{2} \times 10$	$= 140$
CED . . .	$3 \times \frac{4}{2} \times 10$	$= 60$
BGC . . .	$(\frac{2}{3} \times 8 \times 3) + \frac{27}{2 \times 8} \times 10$	$= 177$
This gives a total cubic capacity of . .		702

Having determined the total number of cubic feet, with all deductions and additions, and dividing this sum by the number of persons living in the room, the result is the cubic space per head; whilst the total area of the floor-space divided by the number of persons, gives the floor-space per head; this we know should be as near as possible $\frac{1}{12}$ of the cubic space. When this has been done, the next thing is to count the various openings in the room, and note the direction of movement of the air through them. As a general rule, one-half of the openings will be inlets and the other half outlets, but this is not always so; the actual condition of affairs will be best learnt by observing the directions given to smoke disengaged by smouldering brown paper, velvet, feathers, or even light balloons. The direction of the air-currents being known, their rate of movement must be determined either by an anemometer, if such be available, or by calculation of the theoretical velocity as obtained by Montgolfier's formula, allowance being made, of course, for friction. If the ventilation is meant to be effectual when doors and windows are shut, these should be closed during this examination.

It may be accepted as a good rule that the amount of air issuing up a chimney or other large outlet is a far more reliable index of the fresh air being supplied than the amount actually ascertained to be entering through inlets; in fact, the fresh air supply can be rarely fairly estimated in any other way, as the air, even in the best of built houses, enters through many chinks and crevices, or even through porous walls themselves, in such a way as to be beyond all absolute or accurate calculations.

Having, then, made these various preliminary inquiries, it may be necessary to chemically examine the respired air itself, in which case samples of the air must be taken at such times as will yield fair evidence as to the efficiency or not of ventilation. Thus, in the case of a bedroom, the sample yielded during daytime, with no one in the room, would be no value as an index of the state of the air during the night, when its usual occupants were sleeping in it. Therefore all samples should be collected at an hour when the greatest accumulation of impurities is likely to occur. For

sleeping rooms this will usually be best secured at any hour between midnight and 5 a.m.

For the collection of an air sample, the simplest method is to obtain a glass jar or vessel, provided if possible with an india-rubber cap or stopper, and capable of holding from half to one gallon, and then accurately measure its capacity. If this be filled with clean water, and, after emptying it in the room or air-space it is desired to examine, the jar be then carefully closed with either an indiarubber cap or stopper, the contents of the vessel will be so much of the air required to be examined. Since the amount of hurtful organic impurity in air increases or diminishes with the quantity of carbon dioxide given off by persons inhabiting any particular air-space, the estimation of this gas constitutes the chief chemical examination required for ventilating purposes. For its determination the following method, known as Pettenkofer's, is at once the most simple and the most useful.

Estimation of Carbon Dioxide in Air.—Having filled a Winchester quart bottle, or other suitable vessel of known capacity, with clean water, and emptied it in that part of the air-space it is desired to examine, taking care to let it drain well, pour into it 60 c.c. of freshly prepared lime-water, and close it with an india-rubber cap or stopper. Shake the air and the lime-water in the bottle well up together, and allow to stand for half an hour or so. During this time the carbon dioxide in the air within the bottle will be absorbed by the lime-water, and its causticity or alkalinity lessened. If the causticity of the lime-water be known both before and after the experiment the amount of CO_2 can be calculated that was present in the air of the jar. A solution of crystallized oxalic acid is used to determine the causticity of this lime. This is made by dissolving 2·84 grams of crystallized oxalic acid and making the solution up to one litre with distilled water. One cubic centimetre of this solution is equivalent to 0·5 c.c. of carbonic acid at standard temperature and pressure. Take 30 c.c. of the original lime-water and by titration with the oxalic acid solution determine the exact point of neutralization, using either turmeric paper or phenolphthalein as the indicator. Next determine the causticity or alkalinity of 30 c.c. of the lime-water in the jar in precisely the same way by means of the oxalic acid solution. Twice the difference between the two estimations of alkalinity gives the amount lost by 60 c.c. of lime-water put into the jar, and since each c.c. of oxalic acid solution is equivalent to half a c.c. of carbon dioxide the amount of carbon dioxide in the cubic centimetres in the jar, less 60, is readily determined.

Suppose, in a jar of a capacity of 4385 c.c., it is found that 30 c.c. of lime-water, after standing some while, lose alkalinity,

represented by 6 c.c. of the oxalic acid solution, equivalent to 3 c.c. of CO_2, then for the 60 c.c. of lime-water put in the jar the alkalinity lost is equal to 6 cubic centimetres of carbon dioxide. The original capacity of the jar was 4385 c.c. and this less 60 c.c. for the lime-water put in gives 4325 c.c. of air in which we have found 6 c.c. of CO_2 or an amount equal to 1·38 c.c. of carbon dioxide in 1000 c.c. of air.

If the air of the room be above or below 32° F., a correction must be made by adding or deducting, as the case may be, 2 per 1000, or 0·002 for each volume. The reason of this correction being required is because the ratio between weight and volume of CO_2 as given above is only true for the precise temperature of 32° F., and consequently the volume of air must be corrected for just so much as the heat of the air varies from that temperature. Suppose the temperature of the room, when the sample of air was collected, had been 55° F., that is, 23° above the standard of 32°, therefore $23 \times 2 = 46$ per 1000 of CO_2 must be added to what has been shown above, simply because there was that amount less of air in the jar at that particular temperature than there would have been had the temperature at the time of collection been at 32°; the result of this correction means that instead of 1·38 parts of CO_2 per 1000 of air being present, the true amount is 1·44 per 1000.

A further correction for barometric pressure may be made, if the height of the place is much above sea-level, or if the barometer read below the standard level of 29·92 inches; the correction being 0·26 per cent. for each difference of $\frac{1}{10}$ of a degree in pressure. As a rule, however, this correction is very rarely required.

Estimation of Organic Impurities in Air—Besides the estimation of carbon dioxide, the chemical examination of air, strictly speaking, includes the determination of the organic matter and the ammonia in it. To obtain a merely approximate idea of the organic impurities, the air may be washed or drawn through a very dilute solution of permanganate of potash, of a known strength, and the result expressed as so many cubic feet of the air which it takes to decolourize 1 mgm. of the permanganate. The estimation of the ammonia in air is a still more delicate process, and is performed by washing the air with ammonia free water, and then estimating in the water the ammonia yielded by the air; the actual process is described in the following chapter on water. As tests for the determination of various degrees of respiratory impurity, both the estimation of the organic matter capable of being oxidized by permanganate and of the ammonia present, are quite subsidiary to that for determining the carbon dioxide, and but rarely employed.

Examination of the Suspended Matters in Air.—This will, of course, be essentially microscopic. The suspended matters contained in the air of any particular space or locality may be conveniently collected by drawing the air through distilled water, then, after allowing the suspended matters to subside, to examine them under the microscope; or the air may be drawn or sucked into an exhausted receiver, through a fine aperture, so as to strike upon a piece of glass moistened with glycerine, which, of course, arrests the suspended matters. This is practically the plan of Pouchet's æroscope.

These methods are not sufficiently exact to secure bacteria, moulds, or any of the smaller micro-organisms. Various instruments have been proposed to enumerate and examine the more minute micro-organisms in the air; but, on the whole, the work in this direction has been imperfectly successful. Perhaps the best method is that with Hesse's instrument. He aspirates air slowly through a wide horizontal glass tube, the interior of which, after careful sterilization by heat and washing with alcohol, is smeared or coated with nutrient gelatine. The air enters through a hole at one end, and at such a slow speed as to allow all the suspended particles to fall upon the gelatine before reaching the other end. On being placed in favourable conditions, the various micro-organisms grow upon the gelatine, and can be subsequently examined as to their precise nature. As a rule, the bacteria are much less plentiful than the moulds and fungi, but in air which has been rendered impure by either respiration or by other effluvia, the exact reverse is found to be the case.

In carrying out all inquiries as to ventilation, the various facts connected with the temperature and moisture of the air need to be ascertained. These observations will be best made by means of thermometer to measure the heat, and by hygrometers to estimate the amount of moisture present. Details regarding the nature and use of these instruments will be more conveniently given in a subsequent chapter upon meteorology and meteorological instruments.

In a room, well ventilated and warmed, the temperature should not fall below 60° F., the moisture or humidity ought to range between 72 and 77 per cent., while the carbon dioxide, as previously stated, should not exceed 1·0 part per 1000 volumes of air.

CHAPTER II.

WATER.

Water is found widely diffused in Nature, and enters into the structure of plants and animals as well as nearly every tissue of our bodies. As a solid, we meet with it in the form of snow and ice; as a liquid, in the sea, in streams, rivers, and lakes; while, as vapour, it forms one of the constituents of the atmosphere, and of the breath which we exhale from our lungs. It is by means of the water we take in with our food that the solid portions of it are changed and dissolved, and its nutrient principles enabled to enter into the blood, to enrich it, and thereby build up the body tissues. The supply of water is, therefore, a fundamental necessity, and health depends greatly upon a supply of it, sufficient in quantity and pure in quality.

Water is a chemical compound, consisting of two atoms of hydrogen with one of oxygen, and is formed whenever hydrogen gas or a combustible substance containing hydrogen is burnt in oxygen or atmospheric air. In its purest state it is free from taste and smell, and, between 32° and 212° F., under ordinary atmospheric pressure, is a transparent, tasteless, inodorous, and almost colourless liquid.

In its liquid state, water is about 770 times more dense than ordinary air, this density being actually at its maximum at 39°·2 F. or 4° C. The density of water is always taken as the standard of comparison in reference to the densities of other liquids or solids. In this country the density of water at a temperature of 60° F., and at the standard pressure of the atmosphere, 29·92 inches of mercury (760 mm.), is usually taken as unity, but on the Continent the temperature of its maximum density is more usually adopted, namely, 39°·2 F. or 4° C.; if cooled below or heated above this temperature, it expands. Some idea of the weights of certain volumes of water, in terms of both our own system of weights and measures and that of the metric system, will be gathered from the following table:

Grains.	Cubic centimetres at 4° cent. as grammes.	Cubic inches at 60° F.	Pounds.	Gallons at 60° F.	Cubic feet at 60° F.
1					
15·432	1	0·061		0·0002201	0·0000353
252·456	16·386	1			
7000	454·345	27·727	1	0·1	0·016046
70000	4543·458	277·276	10	1	0·16046
436495	28315	1728	62·355	6·2355	1

Water possesses a certain amount of elasticity and compressibility. This compressibility of water increases as its temperature rises. Water has a high capacity for heat, but yet it is a very bad conductor of heat. When water is heated from below, the heated portions of it expand, and thus, becoming specifically lighter, tend to rise to the surface, while the colder and denser parts of it sink until they, in their turn, being heated, the whole mass acquires a uniform temperature.

At a temperature of 32° F. or 0° C. water becomes solid or freezes, and at the same time suddenly expands; on freezing 1 volume becomes 1·09082, an increase of nearly one-eleventh of its volume, a fact which explains the reason why, during frosts, frozen pipes burst or split, and why damp soils or rocks containing moisture tend to crack during frost. This solid water or ice has a less density than liquid water, its specific gravity being 0·91674, consequently ice always floats on the surface of the water, and, since the density of water is greatest at 39°·2 F., or a few degrees above that of freezing, it consequently follows that such portions of it which are cooled below that point or freeze remain at the surface, while the water just below remains a few degrees warmer.

As already explained in the chapter on "Air," water evaporates from its surface at all temperatures, and its vapour thus formed has a density and tension determined by the temperature. Under the ordinary pressure of the atmosphere, which has also been explained as being equal to 29·92 inches of mercury, water boils at a temperature of 212° F. or 100° C., and is converted into 1672·5 times its own volume of vapour, or roughly 1 cubic inch of water yields 1 cubic foot of steam. If the pressure be reduced to nearly that of a vacuum, the boiling-point of water is nearly that of 32° F. or 0° C.; but if the pressure be increased, then the temperature of the boiling-point is raised, as shown in the following table:—

Pressure, in atmospheres	Temperature of boiling-point.	Pressure, in atmospheres.	Temperature of boiling-point.
	F.		F.
1	212°	8	341·7°
2	250·5°	10	358·8°
3	275·7°	20	418·4°
4	293·7°	25	439·3°
5	307·6°	30	457·1°
6	320·3°	35	472·6°
7	331·7°	40	510·6°

The boiling-point of water under the ordinary pressure of the air is slightly influenced by the nature of the vessel in which it is heated, and by the smoothness or roughness of its surface. Thus in smooth vessels, like those of glass or porcelain, water boils at a higher temperature than in those with a rough surface, like iron. Water has a remarkable power of dissolving substances, and there are but few substances which water cannot to some extent dissolve. Generally the solubility of solid or liquid substances is increased in proportion as the temperature is raised, but there are exceptions to this rule: in the case of gases, the amount which water can dissolve is largely dependent upon pressure; and under ordinary pressure it is generally larger in proportion as the temperature is lower. The watery solution of solid substances and of certain liquids and gases have a higher density than ordinary water, but, as a rule, the density of watery solutions of liquids and gases is less than that of water. The freezing-point of water solutions is lower than that of water, thus sea water, which is largely a solution of various salts of magnesium, sodium, and potassium, freezes less readily than fresh water. The boiling-point of water is raised when it contains solid substances in solution, and this to an extent largely proportionate to the amount of substances in solution.

The latent heat of water is 80 thermal units; the change of one pound of ice to one pound of water at the same temperature requires as much heat as will raise one pound of water through 174·2° F. or 79° C. This quantity of heat represents the latent heat of the fusion of ice or the latent heat of water.

Quantity of Water required.—The amount of water used varies very much in different communities, being dependent on the conditions of the place and population. The following are the gross amounts used in some typical communities, for all purposes, in gallons per head daily: London 32, Edinburgh 38, Manchester 29, Liverpool 31, Leicester 17, Dublin 35, Glasgow 50, Berlin 15½, Vienna 22, Paris 44.

Water is required for drinking and cooking purposes, for personal ablution, for the washing of clothes, utensils, and houses, for the cleansing of closets, and for flushing drains and sewers; these amounts are generally included under domestic supplies. In towns, streets have to be watered, horses and cattle supplied, provision made for extinguishing fires—public fountains and trade purposes generally provided for. Roughly about fifteen gallons per head a day are required for domestic purposes, and about five gallons more for flushing drains and sewers—making twenty gallons; the average for trade and public supplies in towns may be taken at an additional ten gallons. The following table gives in detail the approximate quantities usually allowed:—

	Gallons daily for one person
Cooking	0·75
For drinking	0·33
Baths	5·0
Share of house washing	3·0
Share of laundry washing	3·0
If a general bath add	4·0
Water-closets	6·0
Unavoidable waste	2·92
Total	25·0
For town purposes, etc.	5·0
Add for manufacturing towns	5·0
	35·0

An adult man will drink from 50 to 60 ounces daily, exclusive of the amount of water contained in his so-called solid food; but the quantity varies, depending upon the season of the year and the occupation of the individual. Women and children drink less water than men. With a constant supply in towns there is no doubt considerable waste, and by due economy a smaller quantity would suffice.

The amount required for animals varies, and depends, as in the case of men, on the food, season, and exertion. During hot weather horses need more water than with a cold season. The following quantities approximate as closely as possible to the amount required:—

	Gallons.
Large oxen	6
Small oxen	5
Horses	8
Mules and ponies	6
Sheep or pigs	1

In the army, twenty gallons are allowed daily for each horse.

This amount includes that necessary for the washing of both horses and carriages, and seems ample.

In hospitals a very much larger supply is required, and generally the amount used is double the ordinary supply, the average being from 60 to 70 gallons per head daily.

Rain Water.—All natural water is derived from the rainfall. From the surface of the sea and from the land, water rises, under the influence of the sun's rays, in the form of invisible vapour; it forms clouds by being separated from the air, and descends under changes of temperature in the form of rain, dew, mist, snow, sleet, and hail. Part of this water is again evaporated, part flows off in the form of streams and rivers, while part sinks in through cracks and fissures into the earth until it reaches an impermeable stratum, where it forms the ground water, and flows beneath the surface of the ground at varying levels towards the sea or nearest water-channel, or finds its way to the surface in the form of springs.

Rain water varies with the purity of the atmosphere through which it has passed, and if collected in clean vessels as it falls in the open country, is usually very pure and wholesome. Near the sea it may contain chlorides and sulphates, derived from the sea itself. It is soft, owing to the absence of the salts of lime and magnesia.

As rain descends through the air it takes up from the atmosphere about 25 c.c. of gases per litre, of which about 34 per cent. is oxygen, 64 per cent. nitrogen, and 2 per cent. carbon dioxide. In addition, ammonia is usually present, and any suspended matters which may be floating in the air, so that before it reaches any collecting surface it may have added to it as much as two grains of solid matter in a gallon of water. The average solid impurity in rain water throughout England is 2·4 grains in one gallon of water. In inland districts, especially where large manufacturing works are carried on, these impurities may be increased by the additions of sulphurous and sulphuric acids, and generally with the products of coal combustion, which may be either suspended or dissolved in the air.

Rain water is very frequently contaminated by impurities taken up from the surfaces on which it falls; such impurities generally consist of bird-droppings, decaying leaves, soot, and such matters as collect on the roofs of buildings; if the water is acid it will dissolve lead from the gutters, or zinc, should that metal be present or the water be collected from galvanized iron buildings. In order to prevent the suspended matters passing into the storage tank, a rain-water separator is sometimes used. The separator is made of zinc upon an iron frame, the centre part,

or cantor, being placed upon a pivot; it directs into the lower waste-pipe the first part of the rainfall, which washes away the impurities from the roof. After a certain quantity (about one gallon on each 100 square feet) has fallen, the separator cants over, and turns the clean water into the storage tank. The separator acts automatically.

The rainfall varies in different districts. On the east coast of England it is about 20 inches annually, on the south coast 30 inches, and on the west coast about 70 inches. The mean rainfall for England and Wales may be said to be 34·25 inches annually; for Scotland it is 43 inches, and for Ireland 39 inches.

The quantity of water which can be utilized from the rainfall may be calculated if the amount of the rainfall and the area of the receiving surface is known. It is necessary to know not only the average quantity which falls in any district, but also the amount which falls in the wettest and driest year. Hawksley states that the average of twenty years, *less* one-third, gives very accurately the amount of rain in the driest year; and the same average, *plus* one-third, gives very nearly the amount in the wettest year. The average of the three driest years in twenty is a safe basis on which to calculate the supply.

It is estimated that one-third of the rainfall flows off the surface and finds its way directly into streams and rivers, one-third is taken up by vegetation or evaporated, and the remaining third sinks into the earth; but this can hardly be even an approximation to the truth. The available rainfall for storage will depend rather on the nature of the soil, the inclination of the ground, the temperature and moisture of the air, and the presence or absence of vegetation. On an average six-tenths of the rainfall is available for storage.

A simple method for calculating the amount of water given by rain is to multiply the area of the receiving surface in square feet by half the rainfall in inches, the result is expressed in gallons; the error here is only about 4 per cent. One inch of rain delivers 101 tons by weight, or 22,617 gallons on each square acre. If the inches of rainfall be multiplied by $14\frac{1}{2}$, the result equals the millions of gallons per square mile.

Springs and Rivers.—Rain, flowing over and through the land, supplies springs and rivers. The amount which flows off the surface in streams or which penetrates into the ground depends on the configuration of the surface, the nature of the soil, the season and temperature, and, to a lesser extent, on the movement of the air. In summer, owing to an increase of temperature, evaporation is rapid, and less water penetrates the surface or runs off in the direction of the natural watercourses than in winter;

the ground is drier, and more readily absorbs moisture. Evaporation is 50 per cent. less on a flat district than on an undulating rocky country. In a clay district hardly any water will sink into the ground, while a very large amount infiltrates into a loose sand

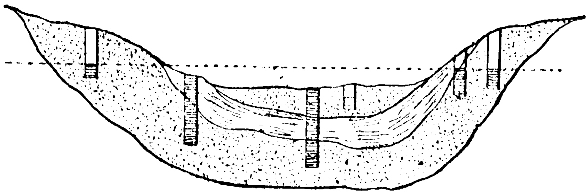

FIG. 13.—Diagram showing the tapping of the ground water above and below an impermeable stratum.

or gravel soil. In the magnesium limestone districts about 20 per cent. of the rainfall penetrates into the ground; in the new red sandstone, 25 per cent.; in the chalk, 42 per cent.; and in loose sands, 96 per cent.

Penetrating into the ground, rainfall absorbs carbon dioxide from the air as it passes through the interstices of the soil, which is nearly 250 times richer in this gas than the air above it; aided by this, by the temperature of the soil and by pressure, it dissolves from the soil limestone and as much soluble matter,

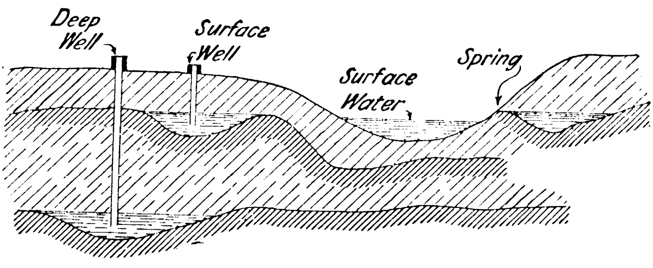

FIG. 14.—Diagram illustrating various sources of water.

from the strata through which it passes, as can be taken up in the time.

It also takes up organic matter from the soil, more especially when it falls on cultivated lands and inhabited areas, and the organic acids derived from this organic matter, aided by increased temperature and pressure, increase the solvent properties of the water by exercising a powerful chemical action on the substances present in the soil and underlying rocks.

Springs are the outcrop or overflow of the ground water. The

rain which falls on a permeable stratum percolates downward until it is arrested by a bed of clay or other impermeable stratum, and there becomes stored underground until it rises to a point or level at which it can spontaneously appear at the surface.

Mineral springs yield water containing dissolved mineral matters in solution which render them unfit for ordinary drinking purposes, though they possess medicinal properties of great value.

River water is derived partly from springs, but its chief source is from that part of the rainfall which flows off from the surface of the ground. If the supply is taken from the head waters or source of the river before impurities can gain access to the water, it is generally pure, and the water has all the characters of an upland surface water. Unfortunately, most rivers are subject to pollution in their course, either from drainage from cultivated lands or from the sewage of villages on their banks being permitted to pass into them. The composition of the water will therefore vary according to the part of the river whence it is taken. As a rule the dissolved mineral constituents in river water are in less quantity than in the spring water, but the organic matters are present in greater quantity. Besides dissolved matters, river water usually contains suspended matter, both organic and inorganic, living and dead.

The organic matter which thus gains access to the water is to some extent oxidized and rendered innocuous in those rivers in which the current is rapid and where the water in its flow is broken up by rocks and boulders and exposed to the action of the air; the presence also of aquatic and bacterial life assists in its purification; but even then this is no safeguard when sewage is permitted to foul the water. Rivers or streams are sometimes dammed up so as to form an impounding reservoir, as in the case of the Vyrnwy, supplying Liverpool, and the Vartry at Dublin. These waters afford good supplies provided the gathering grounds are efficiently protected.

Wells are either shallow wells or deep wells. A well of 50 feet in depth or less is generally regarded as a shallow well; one of 100 feet or more, as a deep well. Shallow wells draw their supply from the subsoil water, while deep wells tap the water-bearing stratum beneath the impervious stratum: the latter are sometimes of great depth, and are called Artesian wells, having been first sunk in the province of Artois, in France. The water from these wells is generally pure, but it is not unusual to find in it a large amount of chloride of sodium and a good deal of free ammonia; it is generally poor in oxygen, not well aerated, but is moderately palatable. Deep-well waters are much harder than other classes of water, for they dissolve out much calcium, magnesium, and the

alkaline salts in their long course underneath the surface of the ground.

Wells furnish water supplies to most rural districts, and their depth generally depends upon the nature of the soil and on the height of the underlying ground water. Shallow wells may yield good water provided there is no risk of pollution from surface washings or from their proximity to drains and cesspools, but in every case it is wise to go deep enough to place an impervious stratum between the water supply and the surface of the ground, and thus to effectually shut off surface impurities from entering and fouling the water in the well. If this cannot be done, the well should be sunk as deep as possible into the water-bearing stratum, and protected by steining with brick and cement, this being carried sufficiently high above ground to prevent surface washings from entering the well (Fig. 15).

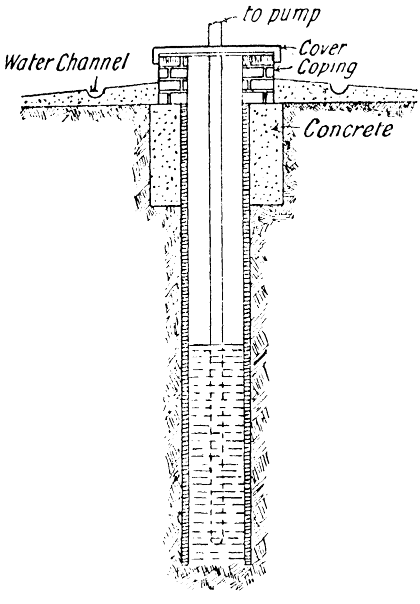

FIG. 15.—Suitably constructed well.

The distance drained by wells is undetermined: it has been given as a circle, the radius of which is the depth of the well, but there are good grounds for believing that much larger areas are affected, and that the flow of water has been influenced at a distance many times the radius; the pressure of tidal rivers has been known to affect the quantity and quality of the water in wells at a distance of 1000 yards. Wells are largely influenced by the nature of the soil, by the movement and direction of the ground water, and by the amount of water drawn from them. A porous soil with no impervious superficial stratum will admit of impurities reaching the well from the surface which a clay soil would shut off. The movement and course of the ground water being in the direction of the nearest watercourse or the sea, to protect the water supply from any soakage from leaky cesspools or other sources of pollution, the well should be placed above

them, to windward, as it were, of all such possible sources of contamination.

A well which yields a moderate quantity of good water may, if the demand on it be increased, draw in water from the surrounding parts to meet the supply, and thus tap sources of impurity which a moderate demand left untouched. A sudden rise in the ground water may also lead to direct communication between a cesspool and a well, by the water tapping the former in its flow.

Tube wells are used when a temporary supply is required: they are superior to dug wells, which, from imperfect steining, or total absence of it, are liable to become foul from surface pollution. They are constructed by driving tubes into the soil, one length being screwed on to another, the first tube being perforated at the bottom for about two feet, its lower end being furnished with a steel point. When the subsoil water is reached, a pump is attached to the tube; the water after pumping a short time is clear.

Collection and Storage.—When water is required for towns it is generally collected in reservoirs and distributed by gravitation. The amount required depends on the quantity used and the ease of replenishing. When these conditions are known, it is easy to calculate the space required; thus, if the number of gallons used daily be divided by 6·23 we get cubic feet, and these multiplied by the number of days for which the storage must last, gives the necessary size of the reservoir in cubic feet. Experience shows that the storage supply in this country should be not less than 150 days' consumption. Hawksley's formula for storage is $D = \frac{1000}{\sqrt{f}}$; where D is the number of days' supply to be stored and f is the mean annual rainfall in inches. Thus, with a rainfall of 36 inches annually, we get $D = \frac{1000}{\sqrt{36}} = \frac{1000}{6} = 166$ days' supply.

Reservoirs are placed on as high ground as possible, to give a sufficient head or pressure of water, so that every part of the district may be supplied by gravitation; from thence the water is distributed by cast-iron pipes. Service reservoirs should be covered and ventilated, and the water from the supply reservoir carefully filtered through filter-beds of sand before it is permitted to enter the service reservoir for distribution. In form they should be deep rather than extended, as this lessens evaporation and secures coolness. In case of ground supplies obtained from wells or springs, the water is generally free from organic growths, and in storing it in service reservoirs it is only necessary that no opportunity should be given for the growth of organisms. If

the supply is taken from surface water there is usually some organic growth present, and the water has to be freed from this by filtration, so as to convert it into a ground water, and then in both cases to protect it from the action of light; it is now recognized that the growth of fungi in water, stored in reservoirs, can be prevented by the exclusion of light. All reservoirs require periodical cleaning.

If the storage reservoir is so large that it cannot be covered in, a second or service reservoir, capable of holding a few days' supply, should be provided, into which, after filtration, the water from the storage reservoir might be conveyed as required.

Distribution.—Water collected as thus described may be distributed on the *constant* system, in which the supply pipes are always kept full of water, or on the *intermittent* system, in which the water is only turned on at intervals for a short time during the day. The constant supply is the one usually aimed at, as no cisterns are required for storage, and the drinking water is taken direct from the main. When the supply is intermittent it is necessary to have cisterns in which to store a sufficient supply of water during the intervals that the water in the mains is turned off; the mains, being empty of water, are liable to be fouled by impurities in the soil, such as gas from leaky pipes lying in their vicinity, or actual sewage from a neighbouring leaky sewer or drain-pipe; the foul air, aided by the suction action of the pipe when the water is turned off, enters through the joints, which are not infrequently caulked with tow and gaskin, and are not impervious. Under proper supervision the waste of water is less on the constant system than on the intermittent system of supply.

Water is usually distributed by iron pipes, called *mains*, laid some distance underground, the thickness of the pipe being dependent on the pressure to which it is subjected by the head of water. The lengths of pipes are put together by a spigot joint packed with lead. The practice of caulking with tow and gaskin and then running the joint with molten lead seldom secures a proper joint; the tow and hemp rot, and contaminate the water as well as causing waste from leakage. Cast-iron pipes, unless protected, rapidly corrode, especially if the water is soft. It is usual, therefore, to coat these pipes with a protective material before laying them down. Angus Smith's process is the one very generally adopted. A varnish distilled from coal tar until the naphtha is entirely removed is deodorized and a small quantity of linseed oil added; this mixture is carefully heated in a tank to about 400° F., when the pipes are immersed in it, and allowed to remain until they attain a temperature of 400° F. Some engineers prefer Barff's method, which consists in raising the temperature of the metal to about 1200° F.—a white heat—in

a suitable chamber, into which is passed super-heated steam; the metal is exposed to this action for several hours, and becomes coated with a protective oxide; this plan has not hitherto proved very successful. Iron pipes last longer if kept constantly full of water, and are not so liable to corrode as those which are alternately full of air and water.

The disadvantage of the constant-supply system is the greater waste from leaky pipes, due to settling of the ground after laying, to fracture from pressure owing to heavy traffic, and the expense of the renewal of the fittings, which must be of the best description; but in practice it has been found that with proper fittings there is no great loss. A plan has been introduced by Deacon by which any large waste occurring in any district may be at once detected. He employs a water-waste meter, or detector, which registers the flow of water both by day and by night. These are fitted to each district main, and as only a very limited quantity is used at night, any waste can be at once detected, since what passes through the meter must run to waste. The place where the leakage occurs can be localized by the vibrations produced in the nearest house-pipes, and which are audible on applying the ear to the stand-pipe. By this method leakage can be at once found out, and an enormous saving of water effected.

Service-pipes communicating with houses are made of lead, wrought iron, or galvanized iron; lead pipes should only be used when it has been proved that the water has no action on that metal. Soft waters are especially liable to act on lead, an oxide of lead being formed which is dissolved again; for such waters, composition pipe, made of an amalgam of lead and tin, has been used, and is said to answer. Iron pipes coated with vitreous glaze are best, and have proved successful when all others have failed, but on account of the difficulty in fixing them, and their cost, they have not come into general use. Galvanized-iron pipes are now very generally used; they are not liable to rust, and stand the pressure of the water well. Block-tin pipes are excellent, but very expensive: water does not act on them, and they last for a long time; their cost, however, is almost prohibitive against their coming into general use. Composite pipes, consisting of block tin enclosed in a lead pipe, are not liable to be acted on by water, but if the surface of the tin is fissured, either in fitting the pipe or by frost, galvanic action takes place, and the lead is rapidly dissolved; they are, however, said to answer where they have been used. The best service-pipes for general use are wrought-iron pipes protected with Angus Smith's preservative:

if pipes coated inside with a vitreous glaze are not considered too expensive, this latter is a perfect material, as it is not affected by acids in the water, and does not yield any unpleasant taste to water. The action of water on iron pipes appears to diminish after their use for a short time.

Cisterns are usually made of slate, stone, iron, galvanized iron, or lead; the latter should never be used when the water supply is taken for drinking purposes. Slate, set in good cement, is an excellent material, but is liable to leak at the joints; in no case should red lead be used to repair these cisterns. Common mortar should not be used, as it gives up lime to water. Stoneware makes a good cistern, but its weight is against its use. Iron cisterns rust and discolour the water; they may, however, be protected by being lined with cement (Crease's patent). Galvanized-iron cisterns are those most generally used; they have been known to give up zinc to water, but this is so exceptional that it should not prohibit their use. They should, however, be thoroughly coated with a good asphaltum paint. Cisterns should be so placed as to be easy of access and readily cleaned. If the water is exposed to frosts, the sides should be made to slope: this will prevent their fracture by the expansive force of the freezing water. The overflow or waste-pipe should not communicate with any drain, but open free to the air above a grating sufficiently high to prevent foul air rising through it and contaminating the water. For the same reason the supply pipe of any water-closet should not pass direct from the cistern, but a smaller cistern (water-waste preventor) should intervene.

To permit of cisterns being periodically cleaned, it is better to have two smaller cisterns than one large one, so that there may be no inconvenience in emptying the one or the other at any time. Cisterns should always be covered to protect them from dust, soot, and other contaminations, as dead mice, birds, etc.; they should also be ventilated and protected as far as possible from both heat and light. Tanks to hold rain water require even more constant care than cisterns, as the water carries impurities with it from the roofs of buildings, from which it is generally collected.

With an intermittent supply, the cisterns in the smaller class of houses are not large enough to fulfil the requirements of the occupants, and stand-pipes are generally erected to supplement the supply; the need of these is avoided where the constant service has been introduced, and the evils attendant upon the storage of water are thereby prevented. A great waste has often followed on the change from the intermittent to the constant service, mainly due to the fittings not being able to stand the greater strain placed

on them; constant supervision is required to see that this is not a cause of waste. Screw-down taps should always be provided, and not a common stopcock, as there is less pressure on the pipe when the water is turned off slowly. The water drawn direct from the main is cooler, and, as a rule, better aerated than when stored in cisterns. A screwcock to turn off the water just as it enters the house is also necessary, so as to shut off the supply if needed; this is very essential during frost, and, if supplemented by a tap at the lowest part of the pipe so as to enable the water to be drawn off, there will be little danger of pipes bursting from this cause.

Pipes, if made of lead, should be sufficiently strong to stand the strain of high-pressure supplies; they are usually 9 lb. per yard for 1-inch pipes, and 21 lb. per lineal yard for 2-inch pipes. In order to limit waste, many companies propose to deliver in special cases water by meter, but this would have the disadvantage, if applied to communities, of restricting the use of water, which is not advisable. The advantages of the constant service in the case of fire is obvious.

Action of Water on Lead.—The apparently inscrutable behaviour of certain waters, especially soft moorland waters, in regard to plumbo-solvent ability, may be said to be now understood. For this explanation we are indebted to the work of Houston. Preliminary inquiry had shown that the plumbo-solvency of any water was associated always with corresponding variations in the amount of acid in the water. Extended inspection and investigation of all the chief moorland gathering grounds has shown that the cause of the plumbo-solvency is due to the acid in the waters, which acid is formed by contact of the water with the moist peat on the catch-ground, and that the formation of the acid is due to the presence of acid-producing bacteria in the peat itself. An important point brought out is a difference in kind of action exercised by water on lead. In one case the action (plumbo-solvency) is brought about by acidity of the water; in the other the action (erosion) is an inherent property of water containing dissolved air. The erosive action, as distinguished from the true solvent action of acid waters, shows itself by the formation of a relatively insoluble compound or powder (hydroxide of lead), which may tend to fall away from the surface of the metal, and so permit of progressive action. Fortunately, however, erosion takes place only to any large extent when the lead is bright, and, moreover, most natural waters contain ingredients which prohibit the action. Neutral distilled water erodes lead vigorously. Interesting as this phase of the subject is, it is quite secondary in practical importance to the question of plumbo-

solvent ability, which is due to acid in the water derived from acid peat, and formed by acid-producing bacteria in the peat itself.

As to remedial measures, the experiments seem to indicate that in practice it might be cheaper to resort to a preliminary lime or combined lime and sand filtration treatment than by employing carbonate of sodium, by this means correcting acidity, plumbo-solvent ability, and gross erosive power, and then supplementing this procedure finally with a further addition of sodium carbonate in minimal quantities, so as, by endowing it with a reserve of protective substances, to place the water in a condition in which the possession of erosive ability would be impossible. There seems to be this difference between erosion and plumbo-solvency, that any mere neutralizing treatment, even if carried out imperfectly, always renders an acid water, as regards plumbo-solvency, less dangerous than before; whereas, as regards erosive ability, insufficient treatment may produce no appreciable inhibition, and may in certain cases render such partially treated water more prone than before to attack lead. In cases where doubt exists as to the plumbo-solvent ability of a water, it is suggested that to be deemed "safe" it should give a neutral reaction with lacmoid solution of an ascertained activity, and also fail to dissolve an appreciable quantity of lead when filtered through a glass tube containing lead shot. Similarly, all doubtful waters should be tested as regards erosive ability by placing them in contact with bright lead. A water containing as much as $\frac{1}{10}$ of a grain in the gallon is unfit for drinking purposes, and even $\frac{1}{20}$ of a grain may be unsafe, as this amount has been known to affect some persons. Filtration removes lead from water, if the filters act properly.

Quality of Water Supplies.—Rain water, if properly collected and stored, affords an excellent supply in country districts. In towns it takes up such impurities from the air and from the various collecting surfaces on which it is gathered, that it cannot be looked upon as satisfactory. The uncertainty of the supply and the length of a dry season necessitates large storage capacity, which is not desirable. Rain water should be filtered to remove suspended matters before being stored, and the tanks protected from light and heat. The hygienic value of rivers, springs, and wells as sources of supply depends on many details. Spring water may be both pure and impure; it is generally, however, free from organic impurity, while its mineral constituents are large. River water, on the contrary, is more liable to vegetable and animal contamination than springs are, while its mineral constituents are less. Shallow-well water should always he viewed with sus-

picion, by reason of the danger from surface pollution during heavy rainfalls.

Hard and Soft Waters.—Water is frequently described as *hard* and *soft*. Hardness is due to the presence in the water of the salts of calcium and magnesium. If it is in the form of carbonates, and if its amount is not excessive, it renders water palatable, and does not interfere with its wholesomeness; but if, on the other hand, it is caused by the sulphates of calcium and magnesium, it is objectionable. Hard waters are also wasteful, as in washing much soap is expended before a permanent lather is obtained. Vegetables boiled in such water tend to become hard, and are difficult to digest. The difficulty of infusing tea with such water is well known.

The following classification show the characteristics of water from different sources (*Rivers Pollution Commissioners' Report*):—

1. In respect of wholesomeness, palatability, and general fitness for drinking and cookery—

Wholesome	1. Spring water	very palatable.
	2. Deep-well water	very palatable.
	3. Upland surface	moderately palatable.
Suspicious	4. Stored rain water	moderately palatable.
	5. Surface water from cultivated lands	palatable.
Dangerous	6. River water, to which sewage gains access	palatable.
	7. Shallow-well water	palatable.

2. Classified according to softness with regard to washing, etc.—1. Rain water. 2. Upland surface water. 3. Surface water from cultivated land. 4. Polluted river waters. 5. Spring water. 6. Deep-well water. 7. Shallow-well water.

3. As regards the influence of geological formation in rendering the water sparkling, colourless, palatable, and wholesome, the following water-bearing strata are most efficient:—

1. Chalk. 2. Oolite. 3. Greensand. 4. Hastings Sand. 5. New Red and Conglomerate Sandstone.

The general characters of a pure and wholesome water are as follows. It should be clear, sparkling, showing that it is well aerated, free from colour and taste, and not too hard, so as to interfere with the cooking of vegetables, etc. There should be no sediment, and if any, it should consist only of a little mineral matter. Where there is any marked deviation from this standard, the cause of it should be carefully inquired into.

Impurities in Water.—The geological formation of a district influences the composition of the water which passes through it;

while affording a valuable guide, it by no means tells with absolute certainty what the constituents of the water may be. The following soils generally yield a supply of pure water:—granite, metamorphic and clay slate soils, hard oolite and chalk. Water from these soils is usually very pure, containing a little carbonates and sulphates of calcium and magnesium, but a very small amount of organic matter. Waters from the sands, sandstones, and gravels vary greatly in composition, and are uncertain sources of supply; the greensand waters are usually good, and in clean gravels, if not situated near towns, the water is often free from impurities. Sometimes the sands contain large quantities of soluble salts, which are dissolved by the water; frequently, also, the organic matter is high. The limestone and magnesium limestone waters are usually free from organic impurity, but may contain the fixed hard salts—calcium sulphate and magnesium sulphate—in excess; they are not as desirable a source as the chalk waters.

The chalk waters are clear, sparkling, well aerated, being highly charged with carbon dioxide; there is usually a very small amount of organic matter present, and, although hard, they can be very effectually softened; they are wholesome waters, as a class, and are pleasant to drink. Fissures sometimes exist in the chalk, by which impure water may be admitted to wells without having undergone any process of filtration.

Surface and subsoil water are a common source of supply in country districts; these waters should always be regarded with suspicion, unless taken from places which are far removed from possible pollution. In gravelly and sandy soils, the power of oxidation is so great that organic impurities become rapidly oxidized and rendered harmless. Such waters are always dangerous, although possibly they may not be actually injurious. Marsh waters are soft and well adapted for washing purposes, but the vegetable organic matter is high, and there is usually much suspended matter present.

Artesian-well water varies; it frequently contains an excess of sodium chloride and carbonate, and there is usually present free ammonia in considerable quantities; it is generally flat and insipid, and for this reason is not very palatable.

Wells situated near the sea-coast usually contain a large amount of saline mineral matter. In cases where this is excessive, surface wells and rainfall afford the only available sources of supply.

Effects of drinking Impure Water.—Although it is a generally recognized fact that any large and sudden outbreak of epidemic disease in a community, especially if it is localized, is usually due to the pollution of the water supply, yet there are many instances

on record where its use has been the cause of ill-health, without producing such marked effects. The diseases which are associated with the use of impure water are cholera, enteric fever and dysentery, dyspepsia and diarrhœa, goitre, parasitic diseases, and metallic poisoning. The virulence of an epidemic disease has some definite relation to the purity of the supply, for, once seeded with the specific poison, a polluted water appears to act more virulently than one that is pure. From our knowledge of the presence of infective micro-organisms, it would appear doubtful whether they survive in good water for any lengthened period. Laboratory experiments show that from 14 to 40 days has been the maximum period of their vitality, and probably under less favourable conditions a much shorter period would complete their life.

Waters containing an excess of the fixed hard salts of calcium and magnesium frequently cause diarrhœa and dyspeptic symptoms, especially among those who are unaccustomed to use them. Carbonate of calcium does not appear to have any injurious effect, nor, on the contrary, is it essential, as it was formerly believed to be; if it is, it is best to have it in some other way than in drinking water. Diarrhœa has been caused by the suspended matters in water, which affect the intestinal tract by mechanical irritation. Waters to which sewage gains access may produce diarrhœa in those who are not used to them, though long habitude in the use of such waters appears to induce a condition in which the system tolerates them. Goitre is a disease said to be caused by drinking water derived from limestone and dolomitic rocks; that goitre is prevalent in places where the water is very hard is undoubted; but it is also said to exist where the drinking water is soft. Modern opinion inclines to the view that the real cause of the disease is a micro-organism which, gaining access to man by means of water which has percolated through a porous and organically polluted soil, subsequently so disturbs the function of the thyroid gland as to set up the condition known as goitre. The whole question is still obscure.

That dysentery has been caused by impure water there is ample evidence to prove; in nearly every instance, the water was polluted with fæcal, and probably with dysenteric discharges, and where the supply was discontinued, the disease disappeared; it may also be said that water contaminated with much suspended matter acts as a predisposing cause by exercising an irritative action on the bowels, as well as being directly the vehicle by which the specific poison is introduced into the system.

Enteric fever is certainly often spread by impure water. In

outbreaks of this nature a suggestive premonitory sign is the prevalence of diarrhœa. The most notable enteric fever outbreaks in which polluted water was shown clearly to be the causative agent have been those at Worthing, Maidstone, Caterham, Middlesbrough and the Tees valley.

Cholera is another disease propagated frequently by means of drinking water infected with the specific micro-organism. The evidence of its spread by this means is overwhelming both in Europe and India. As with enteric fever, so with cholera, the infection gains access to the water by the discharges of those suffering from the disease being allowed to enter defective sewers, leaky cesspools, privies, etc., the contents of which infect the subsoil water or are carried direct into rivers, streams, and wells, from which drinking water is taken.

Ova of parasitic intestinal worms are frequently found in water, and may gain access to man by drinking or bathing. The more common forms are as follows :—*Tænia solium*, *Ascaris lumbricoides* (round worm), *Tænia mediocanellata*, *Bothriocephalus latus*, *Distomum hepaticum* (liver fluke of sheep), *Oxyuris vermicularis* (thread-worms). Also in tropical countries, the *Filaria sanguinis hominis*, the *Filaria medinensis*, the *Bilharzia hæmatobia*, and the *Anckylostoma duodenale*.

Metallic poisoning may result from the absorption by the water of the metal used in the making of the service-pipes, cisterns, etc., by means of which the water is supplied or stored. The water may also be contaminated at its source by passing through a soil in which a metal is present, as in some mining districts, or a river may be polluted with metallic refuse from trade manufactures. Copper, zinc, lead, and arsenic are the most probable poisonous metals which may gain access to water in this way.

Purification of Water.—This subject may be considered in relation to (*a*) purification of water on a large scale as applicable to public water companies, before distribution of the supply, and (*b*) to domestic filtration as usually practised by the consumer in his own house. Water derived from the chalk undergoes a process of purification when the salts of calcium are removed from the water before distribution for the purpose of rendering the water soft. Several methods have been used, but the basis of all of them is the addition of a measured quantity of milk of lime, calculated on the degrees of hardness of the water. Carbonates of calcium and magnesium are soluble in water containing free carbon dioxide. When a solution of fresh slaked lime is added to such a water in proportion to the degree of hardness present, the calcium combines with the excess of carbon dioxide to form

carbonate of calcium, which is precipitated with almost the whole of the carbonate of calcium originally held in solution by the water, and falls as a sediment, carrying down with it the organic impurities held in suspension; this action of adding lime-water to remove the mineral matters (the salts of calcium and magnesium) from a water may be expressed as follows :—

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O$$

It is necessary to know the exact degrees of hardness in the water, and to use only sufficient milk of lime as will combine with the carbon dioxide holding the chalk in solution, otherwise calcium passes out into the distributing pipes. If an excess has been added, a few drops of a solution of nitrate of silver added to a small quantity of the water will produce a dark yellow colour, but only a white precipitate, if chlorides alone are present. The amount of slaked lime added averages about 1 ounce per 100 gallons for each degree of temporary hardness. This treatment usually leaves only the permanent hardness *plus* some two grains per gallon of calcium carbonate in solution. In the Porter-Clark process, the suspended matters are removed by allowing the water to pass through a series of linen cloths under pressure. This has the advantage of rapidity, and removes the whole of the suspended matters effectually.

The permanent hardness of water is not touched by this process; this hardness is due to the soluble salts of calcium or magnesium held in solution by the solvent properties of the water itself

For the reduction of permanent hardness, the addition of sodium hydroxide is needed: thus—

$$CaSO_4 + 2NaOH = Ca(OH)_2 + Na_2SO_4$$

In waters where great permanent hardness is due to calcium salts, then sodium carbonate must be used instead of the hydroxide. In both cases, the addition of lime is needed for removal of the temporary hardness. Practically, each degree of hardness, as $CaCO_3$, is equal to 0·8 part NaOH, 0·56 part CaO, 0·74 part $Ca(OH)_2$, 1·06 part Na_2CO_3, and, for general use, the following rules may be laid down :—

(1) If the temporary hardness exceeds the permanent hardness, add NaOH equivalent to the permanent hardness, and lime equivalent to the excess of temporary over permanent hardness.

(2) If the permanent hardness due to lime exceeds the temporary hardness, add Na_2CO_3 in proportion to the permanent

hardness, and then, if necessary, CaH_2O_2 equal to the temporary hardness.

There are various patent processes in use, such as the Stanhope and Hewetson, which act on the same chemical principles. Another is the Maignen, which treats the water with *anticalcaire*, an agent containing calcium, sodium carbonate, and alum. The Lawrence process of softening is both ingenious and effective, its essential agency is by boiling which both softens and sterilizes the water. That known as the "Permutit" system of softening water employs a compound of silicon, alumina, and sodium; its essential property is base exchange, since as the water passes through the medium the calcium and magnesium are taken up and the sodium salts are freed. The action is automatic and when the "permutit" is exhausted it can be regenerated by a 10 per cent. salt solution, by which the calcium and magnesium are eliminated as chlorides and the reformed soda-permutit ready again to treat more hard water. Manganese-permutit is effective for removing iron from water.

Water is nearly always submitted to some process of storage and filtration before distribution; it is extremely difficult to obtain at its source a water which needs no purification, and in the great majority of cases it is impossible to do so. Water is usually first passed into large reservoirs, where the suspended matters are allowed to subside by gravitation; these consist of mineral grit and clay in a state of fine subdivision and sand, all of which forms a deposit on the bottom of the reservoir. Recent experiences indicate that the advantages accruing from even a few days' storage are very great; this is especially true of river water. The improvements brought about by storage of water in large reservoirs for from one to four weeks are of a general character, and are not limited to the elimination of danger from pathogenic micro-organisms. From the storage reservoirs, the water is led to filter-beds made of sand and coarse gravel, the former being from two to three feet in thickness, and lying on three or four feet of coarse sand and gravel, and from this the water is collected into a storage reservoir for distribution. Downward filtration is much more effectual than the upward or lateral passage of the water through the filter. To secure satisfactory bacterial purity the maximum rate of filtration should not exceed 4 inches, or 2·1 gallons per square foot of filter surface per hour. By these processes two means are employed to purify the water, viz. mechanical and chemical. The mechanical processes consist in allowing the heavier particles to subside, and subsequently arresting the suspended matters on the surface of the filter-beds. Sand filtration has not much effect on the chemical constituents

of the water, but oxidation of the organic matter does to a limited extent follow on passing water through sand filters. The chemical changes produced on water by filtration have up to a recent period been almost the sole test as regards the capability of the material to purify water; recent investigations show that all that is really necessary is that mechanical filtration shall be perfect. Sand, although its effect on the organic constituents in water, as gauged by chemical analysis, is limited, is very effective in holding back micro-organisms, which, if they are not the actual cause, are intimately associated with those diseases spread by the agency of water, such as enteric fever, cholera, dysentery, etc. The chemical action which takes place is probably due to the presence of a nitrifying ferment in the sand as well as to air in the interstices of the sand itself; this action is not, however, regarded as being of much importance. The mechanical action which frees the water from micro-organisms is largely assisted by the deposit of slime on the surface of the filters, and it is now recognized that in sand we possess a most powerful medium for removing germs from water. Two conditions are, however, necessary to obtain the best results; these are (1) that the sand should be of a certain thickness, not less than 30 c.m. (1 foot), and (2) that the water should not flow through it at a greater pace than 4 inches in one hour, or 50 gallons daily per square foot of surface. The action of this filter is partly mechanical, partly vital; the mechanical action is confined to the holding back of the grosser substances which have not subsided, but remain suspended in the water; the vital action consists in the layer deposited on the surface of the sand which is charged with microbian life, and it is by these organisms, which are constantly increasing in number, and which penetrate the sand to a slight distance, that both the nitrification of organic matter and the arrest of other microbes is effected. From this it is evident that in order to preserve the power of these filters, the surface layer should not be removed so long as water passes through it. Roughly stated, it may be said that a filter becomes "dead" (*i.e.* nearly impervious to water), and consequently demands cleaning once every three or four weeks in summer, and about half as frequently in winter; but it is not possible to lay down hard and fast general rules applicable to all filters. In some experiments recently undertaken in America, to test the power of sand filters in removing pathogenic bacteria, and especially that associated with typhoid fever from drinking water, it was found that 99½ per cent. of the applied bacteria were removed, and this goes to prove that these filters act efficiently when properly constructed as a safeguard against water-borne diseases. The rate of flow through the filter must not exceed 4 inches in one hour,

and the rule should be that no water can be regarded as efficiently filtered that contains more than 100 micro-organisms in 1 c.c. of the filtered water. But cases will arise in which it is necessary to purify water, and when no regular system of filtration as above described exists or is possible, simpler and often ruder methods are all that can be devised.

Owing to their relatively slow rate of filtration, the gravity sand and gravel filter-beds have been subjected to some criticism. As an outcome of this criticism, installations have been devised in which the water receives from $\frac{1}{10}$th to 1 grain of sulphate of alumina per gallon; this serves as an adjuvant to the filter for the holding back of micro-organisms and fine suspended matter in the water. Filters of this kind have the sand contained in steel drums, and the water is passed through under pressure; 600 square feet of filter surface purifying satisfactorily a million gallons of water daily. An efficient representative of this type is the Bell Patent Filter. Another kind of filter is that known as the Candy filter. In this system no chemical coagulants are used; the water to be purified is first saturated with air, forced in under pressure, and then strained by passing it through sand contained in cylindrical chambers or drums. This procedure is very successful in removing iron and lead from waters, while the degree of bacterial purification is stated to average 93 per cent.

Apart from the above methods, successful purification of water on a large scale can be secured by chlorination. This is done by the addition of bleaching powder or a solution of hypochlorite of calcium, sodium, or magnesium, so that there is maintained in the water 1 part per million of available chlorine for half an hour. The carbonic acid naturally present in the water liberates hypochlorous acid from the hypochlorite of calcium or other salt used. The bleaching powder is changed into harmless calcium carbonate and calcium chloride. The amount necessary to be added can be determined by testing for free chlorine by means of potassium iodide and starch fifteen minutes after the addition of the chlorinated lime. If a blue colour appears when the chlorinated water is mixed with the iodide and starch, some free chlorine is present and it is unnecessary to add more of the chlorinated lime. If no blue colour appears there is still need for free chlorine, and more of the chlorinated lime must be added and the test repeated.

In a permanent chlorination installation it is necessary to remove the residual chlorine before it enters the mains. This can be done by means of bisulphite of soda, but more generally by passing the sterilized water through filters of vegetable charcoal, which remove all odour and taste from the chlorinated water. The chlorination process is less costly than sand filtration

and equally efficient. It is particularly suitable for river waters used as a source of supply. This chlorination process has been much used in the army during the great war and is coming into use among civil communities. Other methods, such as ozonisation and treatment of water by ultra-violet rays of light, have been suggested for water purification; as yet they have not reached the economically practical stage.

The foregoing methods are all designed for dealing with water in considerable quantities. Although it is customary for water supplied by public companies to be sufficiently purified before distribution, yet circumstances exist in which domestic filtration is often a necessity. Among the number of substances suggested or used for this purpose, animal charcoal, either in granules or made into silicated blocks, has long been very popular. Modern experience shows that, although charcoal possesses considerable oxidizing powers on the organic impurities dissolved in water, it does not sterilize it, but, on the contrary, permits micro-organisms to pass through unchanged. The suspended matters tend to deposit on it, forming a slime on the surface, which contaminates the water it is supposed to purify. A filter which depends on a block of carbon alone is useless for the purposes of filtration.

Recent investigations go to show that the value of any filter does not so much depend on its action on the chemical constituents of a water supply as on its power of holding back micro-organisms, which are now generally admitted as being closely connected with the specific diseases.

Judged by this standard, the only materials suited for filtration work are certain infusorial earths, clays, porcelain, or patent combinations of porcelain with clay. The best modern domestic filters are those made of judicious mixtures of selected clays: these are moulded into tubes or bougies, enclosed in metal jackets, and the water forced through them under pressure, varying from 20 to 40 lbs. on the square inch. The usual type of these filters is shown in Fig. 16, where the filtering tube is attached to an ordinary tap and the water forced through the medium by the pressure of the water in the main. In the portable or detachable types, the water is placed under pressure by means of an attached pump and so forced through the filter.

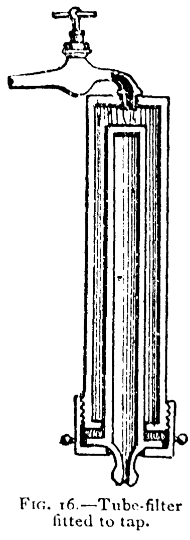

FIG. 16.—Tube-filter fitted to tap.

These filters act on water precisely as sand filters act on a large scale: they sterilize the water—that is, the pores are so

small and the current of water so finely divided that micro-organisms are unable to pass through. The filters have no action on the dissolved organic impurities in water, but it is of no less importance that water intended for drinking purposes should be free from these, as with such, no doubt, is associated the multiplication of micro-organisms, if not their virility and potency.

The rate of filtration through these filters depends mainly on the pressure of the water, which passes from without inwards. This is convenient, as the deposit, which tends to be and is gradually formed on the outer surface during use, can be easily washed or brushed off on removing the screw-tap. Although these "bougies," or candles, deliver sterile filtrates for a considerable time, often when left uncleaned, it must be remembered that they cannot do so indefinitely. Experiments have shown that, when immersed in foul or polluted water, these filters, particularly those whose lacunar spaces are large, permit of the growth of pathogenic bacteria through their substance, and ultimately fail to yield sterile filtrates. This growth of bacteria through these filters may take place in as short a period as four days, hence the necessity, especially when foul water has been subjected to filtration, of sterilizing the filters every three days by careful immersion and scrubbing of their surfaces in boiling water. The only bougies which have failed to permit of bacterial growth through their interstices are the tubes or candles made of porcelain or clays of very close texture. They, though certainly more reliable, deliver water much more slowly than others of a more open texture.

For the purification of water by heat there are three methods; these are distillation, boiling, and the employment of special apparatus working on the heat exchange principle.

Distillation is employed rarely on land, its applicability is limited practically to shipboard and to a few places abroad dependent upon sources of supply which are not only organically impure but also brackish. The final product is often flat and dull owing to loss of dissolved gases; one of the greatest of objections to distilled water is its indifferent storage qualities particularly in hot countries.

Boiling is limited to the purification of water in small quantities, and though ensuring the destruction of micro-organisms, presents the objection of being extravagant in fuel, makes the water flat and insipid, and leaves the finished article hot and of limited utility.

To overcome this last objection various special apparatus designed on the heat exchange principle have been invented. These sterilizers utilize the fact that, with a sufficient area of metallic surface of good conducting capacity and sufficient time,

a given quantity of hot liquid will yield nearly all its heat to an equal amount of similar but cold liquid. By adopting this principle large quantities of water can be rapidly treated and as rapidly cooled with the result that a volume of water is sterilized quickly, retains its dissolved gases, issues from the apparatus nearly as cold as it went in, and with the expenditure of a small quantity of fuel. The majority of apparatus designed on this principle bring the water to the boil and depend upon the expansion of the boiling water for the maintenance of a circulation of the liquid through the machine. For the actual sterilization of water ebullition is unnecessary, it being sufficient to maintain the water at 180° F. for a few seconds to secure the destruction of the disease-producing micro-organisms usually found in water. In apparatus designed on this fact, it is essential to employ some form of valve or thermostat to control the flow of water, or rather not to permit of the passage of water over to the cooler unless it has been maintained at 180° F. for the requisite period of time. Except for isolated houses dependent on an impure supply of water, we question whether there is much scope for these methods. The same remark applies to certain chemical methods for sterilizing water on a small scale, such as the use of alum, permanganate of potassium, iodine, or bisulphate of sodium. They are essentially academic methods, and in the hands of unscientific people likely to do more harm than good.

Water Analysis.

The results of a sanitary analysis of water must be considered in connection with many conditions, such as the locality and surroundings of the water, the depth or rate of flow of the river or lake, the season of the year, the conditions of the catchment area, etc.; if wells, their proximity to the sea, their depth, and, if possible, the strata through which they pass. Conditions such as these largely affect the interpretation of the results which a chemical analysis of a water gives. For example, the limit of free ammonia and chlorine allowed in a water taken from a deep well of 800 or 900 feet, would, if present in a surface well of 20 or 30 feet in depth, indicate contamination of a serious kind. The object of an analysis of water is to determine the amount of mineral and organic constituents, and to note for future examination the character of the suspended matters.

At the outset, a knowledge of the source of the water is necessary, whether a surface water or ground water. A surface water nearly always contains animal and vegetable life, while water from the deeper strata is usually devoid of life until it is

exposed to the action of light and air in reservoirs, under which conditions it assumes in this respect the characters of a surface water.

Collection of Samples.—In order to secure that the results of an examination of water should be of value, care must be exercised in the collection of the samples. Winchester quart bottles, holding half a gallon, are very suitable for the purpose; the bottle used should be carefully cleansed with a little hydrochloric or sulphuric acid, and then thoroughly washed out with pure distilled water or some of the water to be examined. When a sample is taken, the bottle should be filled quite full, and just sufficient poured off so that a little air-space is left under the stopper, care being taken that the inside of the neck of the bottle or the stem of the stopper be replaced untouched by the hand or wiped with a cloth. Corks should not be used except in great emergency, and then only if they are quite new and thoroughly rinsed in water before being used. No luting of wax plaster or similar material should be used.

In taking samples from streams, lakes, or reservoirs, the bottle should be submerged with its stopper in the water, and the stopper withdrawn 12 inches or more below the surface, so as to avoid collecting any of the water that has been in immediate contact with the air. If from a public water supply, the sample should be drawn from a hydrant in direct connection with the main, and not from a cistern or storage tank; if taken from a service pipe, the water should be allowed to run to waste for some minutes before it is collected, in order to remove that which has been standing in the pipe; the bottle should then be rinsed out at least three times, pouring out the water completely each time; the same practice should be adopted in the case of pumps. Water should be examined as soon after collection as possible, and kept in a cool place not exposed to light.

It is important that with each sample the fullest information should be given of those conditions and surroundings which may influence the character of the water; especially must be noted the *source* of the water, whether from wells, rivers, cisterns, public supplies, etc. If a well, the depth and the depth of water in the well, whether steined or otherwise, the strata through which it is sunk, the position and distance as regards cesspools, privies, drains, etc., whether the land around is cultivated, whether a pump is attached, and if not, how the water is raised. If a cistern, how supplied; if by rain, the nature of the collecting surface and storage. If a public water supply, the source, and whether the water is supplied on the constant or intermittent system. It should also be stated whether any disease is suspected to have been caused by the water, so that a bacteriological exami-

nation may be made if considered necessary. No point likely to afford information should be omitted.

Physical Examination of Water.—Water should be clear and free from turbidity. *Turbidity* is caused by the suspended matters in water, that which on standing for some hours settles to the bottom is its *sediment*. As a rule, surface waters are turbid, deep-well waters clear; the suspended particles may be finely divided clay, algæ or some other living form, animal or vegetable. The *colour* of water may be judged by looking through a stratum of water 12 inches deep; this can be done by using a tall glass placed on a sheet of white paper. Pure water is generally of a bluish or greyish colour. Yellow or brown waters are suspicious, as they frequently owe their colour to sewage, unless in peat districts or in places where iron is found, in which case the waters are not usually hurtful. The *taste* of water is a most uncertain guide; the taste depends almost altogether on the gases dissolved in the water, and not upon the soluble animal and mineral matters, unless these are in large excess. Any badly tasting water should be rejected. Taste also differs much in different persons. Common salt can only be tasted when 75 grains are added to 1 gallon of distilled water, and the other mineral constituents usually present must be large before they can be recognized. Iron is the only substance which can be tasted in small quantities.

The *odour* of water is best detected by heating it in a stoppered flask to 80° F. As a rule, the odour only lasts for a few moments, and should be judged by removing the stopper and smelling the water at once; it is sometimes a guide in polluted waters, and gives a clue to the origin of the pollution. Any offensive smell is sufficient to condemn a water.

The physical characters of a pure and wholesome water are freedom from any marked colour and from suspended matters, a brilliant lustre, devoid of any taste or smell. In a large majority of cases, water possessing these characters is fit for drinking purposes.

It is not intended in this manual to treat fully the subject of water analysis, which requires much elaborate apparatus and considerable chemical knowledge, but a few qualitative and quantitative tests are given, capable of indicating the general characters of a water.

Qualitative Examination of Water.—The *reaction* of pure water is usually neutral. If acid and the acidity disappears on boiling, it is due to carbon dioxide. If alkaline and the alkalinity disappears on boiling, to ammonia. If permanently alkaline, it is probably from sodium carbonate.

Litmus and turmeric papers are used to determine the reaction, which is usually red or yellow if acidity be present.

Hardness.—Add oxalate of ammonium; if calcium is present, a white precipitate is formed: 6 grs. per gallon gives turbidity, 16 grs. a considerable precipitate.

Chlorides, with nitrate of silver and dilute nitric acid, give a white precipitate: 1 gr. per gallon gives a haze, 4 grs. per gallon gives a marked turbidity, and 10 grs. a considerable precipitate.

Nitrates.—Add a solution of brucine (1 grm. in 1 litre of distilled water) and strong sulphuric acid. The sulphuric acid should be poured gently down the sides of the test tube to form a layer under equal parts of a mixed water and brucine solution. Half a grain of nitric acid per gallon gives a marked pink-and-yellow zone; or 2 c.c. of the water may be evaporated to dryness and a drop of strong sulphuric acid and a minute crystal of brucine dropped in—0·01 gr. per gallon can be easily detected.

Nitrites.—Nitrous acid decomposes iodide of potassium, and free iodine gives a blue colour with starch. Boil 20 grms. of starch intimately mixed with half a litre of distilled water; filter when cold, and add 1 grm. of potassium iodide. If a little of this solution is mixed with the water to be examined, and dilute sulphuric acid added, an immediate blue colour will appear, should nitrites be present; or Griess's test may be employed. To 100 c.c. of the water add 1 c.c. of metaphenylenediamine solution (made by dissolving 5 grms. of metaphenylenediamine in 1 litre of distilled water, rendered acid with sulphuric acid, and decolourized, if necessary, with animal charcoal) and 1 c.c. of dilute sulphuric acid (1 in 3). A yellow colour, changing to red, will appear in the water in half an hour if there be only one part of nitrous acid in ten millions of water.

Ammonia is detected by Nessler's solution; if present in water, a yellow colour or yellow-brown precipitate is formed. If in small quantity the colour should be observed through a column of water 4 or 5 inches in depth, the glass being placed on a white ground.

Iron.—Ferrocyanide of potassium (yellow prussiate) gives a blue colour with ferric salts, and ferricyanide (red prussiate) with ferrous salts. The water should be rendered acid with dilute hydrochloric acid, free from iron. A comparative test should be made with distilled water.

Lead or Copper.—Place some water (100 c.c.) in a white dish, and stir with a rod dipped in ammonium sulphide; wait till colour is produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.

The following test is best applied to water concentrated to one-fiftieth part of its original volume:—

Magnesia.—Add oxalate of ammonium to precipitate the lime, then after filtration a few drops of phosphate of sodium, of chloride of ammonium, and of liquor ammoniæ. A white crystalline precipitate of magnesium-ammonium phosphate appears within twenty-four hours.

THE QUANTITATIVE ANALYSIS OF WATER.

The chief points which require determination in an ordinary quantitative analysis are the total solids, the chlorides, the hardness, and the organic matter as represented by what are called the free and albuminoid ammonia. If additional evidence as to the quality of the water is required, to these may be added the determination of the amount of oxygen absorbed, and the amount of nitrogen existing as nitrites and nitrates.

The main principle of a quantitative, or volumetric analysis, is the submission of the substance to be estimated to certain characteristic reactions, employing for such reactions solutions of known strength; and from the volume of solution necessary for the production of the reaction, determining the weight of the substance to be estimated by the application of the known laws of chemical equivalence.

To carry out any quantitative analysis, the first essential is the thorough comprehension of the simple relationship between liquids and solids. Owing to its uniformity and simplicity, in the following analytical methods, the metric system alone will be mentioned. Although tables of the various metric weights and measures are given in the Appendix, it may not be out of place here to emphasize the fact that a cube of distilled water at its greatest density, viz. 4° C., or 39° F., whose side measures 1 decimetre, has exactly the weight of 1 kilogramme, or 1000 grammes, and occupies the volume of 1 litre, or 1000 cubic centimetres. In other words, 1 cubic centimetre, as a measure of volume, equals or corresponds to 1 gramme as a measure of weight, and that

Grammes	of a subst.	diss. in	10	c.c.	of water	are	x	parts in	10
,,	,,	,,	100	,,	,,	,,	x	,,	100
,,	,,	,,	1000	,,	(1 litre)	,,	x	,,	1,000
Decigrammes	,,	,,	,,	,,	(1 litre)	,,	x	,,	10,000
Centigrammes	,,	,,	,,	,,	(1 litre)	,,	x	,,	100,000
Milligrammes	,,	,,	,,	,,	(1 litre)	,,	x	,,	1,000,000
,,	,,	,,	100	,,	of water	,,	x	,,	100,000
,,	,,	,,	10	,,	,,	,,	x	,,	10,000
,,	,,	,,	1	,,	,,	,,	x	,,	1,000

It is most usual, in this country and on the Continent, to

express the results of a quantitative analysis as parts per 100,000 —that is, centigrammes per litre, or milligrammes per 100 cubic centimetres. This ratio will be adopted in the following analytical processes, while, for the sake of brevity, the term "cubic centimetre" has been written as c.c.

Occasionally, the expression grains per gallon is met with in English analysis. This is equivalent to parts per 70,000, as there are 70,000 grains in a gallon. The conversion of parts per 100,000 to grains per gallon is, of course, readily performed by multiplying by $\frac{7}{10}$, or by 0·7; and from grains per gallon to parts per 100,000, by multiplying by 10 and dividing by 7

The Apparatus specially needed for making a Quantitative Analysis consists of—

1. *A pair of balances, and weights* according to the metric system. In these sets of weights, the larger ones represent grammes, the next in size decigrammes, and the next centigrammes. Small forceps are used for picking up and applying these weights to the pans of the balance. The milligrammes are added by shifting a little piece of bent wire along the cross-beam of the balance, which has on it ten markings, numbered from 1 to 10, on either side of the pivot.
2. *A platinum dish*, capable of holding 200 c.c. of water.
3. One or more shallow *porcelain evaporating dishes*, capable of holding 300 c.c.
4. A small *porcelain crucible*, with lid, for igniting residues.
5. *A pestle and mortar*, for powdering reagents previous to solution.
6. One or more *retorts*, or boiling flasks.
7. A Graham's, or Liebig's *condenser*.
8. Six *Nessler Glasses*, each capable of holding 100 c.c.
9. Glass *stirring-rods*.
10. Two glass-stoppered bottles, capable of holding 250 c.c.
11. Glass *funnels* for filtering.
12. A packet of Swedish *filter papers*.
13. A dozen *test tubes*, with stand, cleaner, and holder.
14. A *measuring flask*, to hold at least 1 litre and graduated in cubic centimetres.
15. Glass *burettes*, or graduated tubes, holding 50 c.c., and graduated in cubic centimetres and tenths of a cubic centimetre. One of these should be mounted on a wooden stand, and be provided with a stopper at the top, and fitted with a stop-cock at the bottom.
16. *Glass pipettes*, graduated to deliver 10, 20, 50, or 100 c.c.
17. An iron tripod.
18. One or more triangles of iron wire, covered with pipeclay.

19. A pair of small crucible tongs.

20. A long thermometer, graduated in either Centigrade or Fahrenheit degrees.

Standard Solutions required in a quantitative analysis, are solutions of definite strength, made by dissolving a given weight of a reagent, in grammes, in a definite volume of distilled water in cubic centimetres. These solutions are usually made by dissolving either the hydrogen equivalent weight of a reagent in grammes, or some decimal part of such weight in 1000 c.c. (1 litre) of water. The following abbreviations are often used to express the strength of these solutions :—

N = a normal solution having hydrogen equivalent weight in grammes per litre					
$\frac{N}{2}$ = a semi-normal	"	$\frac{1}{2}$	"	"	"
$\frac{N}{10}$ = a deci-normal	"	$\frac{1}{10}$	"	"	"
$\frac{N}{20}$ = a viginti-normal	"	$\frac{1}{20}$	"	"	"
$\frac{N}{100}$ = a centi-normal	"	$\frac{1}{100}$	"	"	"
$\frac{N}{1000}$ = a milli-normal	"	$\frac{1}{1000}$	"	"	"

In place of using the above normal or deci-normal solutions, it is often found convenient to use what may be called a standard solution—that is, a solution of a reagent so made that a cubic centimetre has a value expressible as unity or some convenient figure or factor. Thus, an empirical standard solution of silver nitrate can be made to the strength that 1 c.c. is capable of precipitating 1 mgm. of chlorine. This is made by dissolving, not the hydrogen equivalent weight of silver nitrate, but that fractional part of it which is equal to one of chlorine. Taking $AgNO_3$ to be represented by 170, in terms of its hydrogen equivalent weight, and chlorine as 35·5, then 4·788 grms. of the silver nitrate dissolved in a litre of distilled water, would give a solution, a cubic centimetre of which would exactly equal 1 mgm. of chlorine.

Occasionally, in making standard solutions the equivalent hydrogen weight of a reagent cannot be taken, but its particular weight in a particular reaction in a given analysis has to be regarded. For instance, when using a solution of potassium permanganate, as an oxidizing agent, having the chemical formula $KMnO_4$, and the molecular weight of 158, and yielding five atoms of oxygen in a particular reaction, its normal solution is

made by dissolving one-fifth of its molecular weight, $\frac{158}{5}$, or 31·6 grms. in a litre of water. In other instances, when the hydrogen equivalent weight of a substance is not identical with the atomic or molecular weight, the amount taken is the equivalent weight. Thus, oxalic acid, $C_2H_2O_42H_2O$, (with an atomic weight of 126, is a dibasic substance, and its equivalent weight is one-half of its molecular weight; consequently, a normal solution of oxalic acid would be made by dissolving 63 grms. of the crystallized acid in 1 litre of distilled water. Similarly phosphoric acid, which is a tribasic substance, would require, for the preparation of a normal solution of sodium phosphate, $Na_2HPO_412H_2O$, one-third of its molecular weight $\frac{358}{3}$, or 119·3 grms. being dissolved in distilled water and made up to 1 litre.

Indicators.—In order to enable us to ascertain, by a change of colour or other marked effect, the exact point at which a given reaction is complete, certain substances, called indicators, are employed. The chief are as follows:—

(*a*) *Solution of litmus*, which turns red with acids and blue with alkalies.

(*b*) *Alcoholic solution of phenol-phthalein*, which is colourless with acids, but becomes red with alkalies.

(*c*) *Starch mucilage*, which turns blue in the presence of free iodine.

(*d*) *Solution of potassium chromate*, which gives a red with nitrate of silver, but not until all the chlorine or halogen present has entirely combined with the silver.

Estimation of Total Solids in a Water Sample.

The estimation of the total solids, by itself, is not of very great practical hygienic value, but affords a control over the other quantitative determinations. Take 250 c.c. of the water sample, place in an evaporating dish, and slowly evaporate down to 100 c.c., or less, carefully guarding against any of the solids remaining attached to the sides of the dish. Transfer the concentrated water and residue to either a small, clean, weighed crucible, or platinum dish. Evaporate to complete dryness, in air, water, or steam bath, at 105° C. So soon as the capsule is cold, reweigh: the difference in weight will be the amount of *total solids*. A simple form of steam bath can be made by taking a common two-gallon tin can, fitting a perforated cork into its mouth, and passing a funnel through the perforation. The crucible is placed in the funnel, water boiled in the tin can, and a little roll of paper placed between the funnel and the crucible to let the steam pass out.

Example.—Total solids, 250 c.c., dried as described—

	Grammes.
Weight of dish and residue	23·14
,, ,, alone	23·09
Difference being total solids in ¼ litre of water . . . or 0·05 part in 250.	0·05

This multiplied by 400 or 0·05 × 400 = 20 parts of total solids in 100,000.

After the total solids have been determined, they should be slowly incinerated over a flame to dull redness, when any organic matter will give evidence of its presence by charring or by yielding dark fumes with the smell of burnt horn. Continue the incineration until nothing remains but a clear white mineral ash. If iron be present, the ash may be red; whilst manganese gives it a greenish tint. Having allowed the capsule to cool, weigh again; the excess weight now over that of the clean and empty dish represents the *fixed solids*, and the difference between them and the total solids gives the *volatile solids*.

Fixed Solids.—The above residue is incinerated as described.

	Grammes.
Weight of incinerated residue and dish	20·12
,, dish alone	20·09
Difference being fixed solids in ¼ litre of the water .	0·03

This multiplied by 400 or 0·03 × 400 = 12 parts of fixed solids in 100,000.

Volatile Solids.

Total solids	20 parts per	100,000
Fixed ,, ...	12 ,,	,,
Difference being volatile solids . . .	8 ,,	,,

The total solids consist in most water samples of carbonates of calcium, sodium, magnesium, potassium, and iron; sulphates and chlorides of sodium, calcium, and magnesium; nitrites and nitrates of calcium, sodium, and potassium; with occasionally some phosphates of potassium and sodium.

The volatile solids consist generally of ammonium salts, nitrites, nitrates, some of the chlorides and carbonates, with water from sulphate of lime and destructible organic matter.

The amounts of total solids vary from 3 or 4 to 50 or 60 parts per 100,000. Of these not more than 3·0 per 100,000 should be volatile or lost on ignition.

Estimation of Chlorides in a Water Sample.

For this purpose two solutions are required.

(1) *A solution of Potassium Chromate*, made by dissolving 50 grms. of the salt in a litre of distilled water. Nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle and the clear liquid decanted off.

(2) *A deci-normal standard solution of Silver Nitrate*, made by dissolving 17 grms. of $AgNO_3$ (molecular weight being 170) in a litre of distilled water. This will be equivalent to one-tenth of the atomic weight of chlorine (35·5), or 3·55 grms. of chlorine, and 1 c.c. of this solution will equal 3·55 mgms. of chlorine.

The process consists in taking 250 c.c. of the water sample, placing them in a white porcelain dish, and rendering them of a distinct yellow colour by means of two or more drops of the potassium chromate solution. From a burette, run in drop by drop some of the $\frac{N}{10}$ silver nitrate solution, stirring after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. As each cubic centimetre of the silver solution equals 3·55 mgms. of chlorine, the number of cubic centimetres used indicates the milligrammes of chlorine in 250 c.c. of the water--that is, parts per 250,000—and that divided by 2·5 or multiplied by 0·4 will give parts of chlorine for 100,000.

Example.—In 250 c.c. of water, rendered yellow with potassium chromate, 1·5 c.c. of silver solution gave a permanent red tint; then—

$$\frac{1·5 \times 3·55}{2·5} = 2·13 \text{ parts of chlorine per } 100{,}000$$

The purest water, as a rule, contains less than 1·5 parts of chlorine per 100,000. An increase may be due to sea water, to percolation through salt-bearing strata, to sewage or other impurities. Some deep wells often contain large quantities of chlorides; but generally an excessive presence of chlorides is a reason for suspicion unless a satisfactory explanation of their presence is obtainable.

Estimation of Hardness in a Water Sample.

The hardness of a water is conveniently determined by means of the soap test. Soap is the oleate of an alkali metal resulting from the combination of an alkali metal with one or more of the fatty acids, *i.e.* oleic, stearic, or palmitic acids. When an

alkaline oleate is mixed with pure water a lather is given almost immediately, but if salts of calcium, magnesium, aluminium, barium and iron, or other similar substances are present in the water the soap forms oleates with these bases, and no lather is formed until these earthy bases are thrown down or used up. The hardness of a water depends upon the presence in it of more or less of these earthy bases, and the more they are present the greater will be the expenditure of soap to make a lather. Free carbon dioxide has a similar effect. The soap combines in equivalent proportions with these bases, so that if a solution of soap be graduated by a solution of known strength of any one of them, it will be of equivalent strength for corresponding solutions of any of the others. Owing to magnesia having a tendency to form double salts with the fatty acids, the results are not quite so accurate as for calcium or barium. A certain amount of the hardness of a water is removed by boiling, hence it is usual to speak of the hardness present before boiling as total hardness, that remaining after boiling as fixed or permanent hardness, and that which has been dissipated by the boiling as the temporary hardness.

The total hardness in most drinking waters is caused by salts of calcium and magnesium with some free carbon dioxide. Hence waters from the chalk, oolite, limestone, dolomite, and new red sandstone are apt to furnish the greatest degrees of hardness. Rain water, being free from these salts, is usually very soft. Many of the salts contributing to the total hardness are held in solution by carbon dioxide, and when the water is boiled this is dissipated, causing these salts to fall to the bottom or form incrustations on the sides of the containing vessel as insoluble salts. The chief of these are carbonates and sulphates of calcium and magnesium, with silicates of iron and aluminium when these are present.

The permanent hardness, or what still remains in solution, consists mainly of some sulphates, chlorides, and nitrates of calcium and magnesium, with a little iron and aluminum.

The Soap solution for the estimation of hardness is best made by thoroughly dissolving by stirring and warming some soft soap in a mixture of 4 parts methylated spirits to 6 of distilled water, and then filtering. This solution of soap should be standardized—that is, diluted or strengthened as the case may be, so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of nitrate of barium. Barium nitrate $Ba(NO_3)_2$ has a molecular weight ratio to calcium carbonate $CaCO_3$, of as 261 is to 100, and if 0·261 grm. of barium nitrate be dissolved in a litre of distilled water, that solution equals 0·1 grm. of calcium carbonate, and 50 c.c. of the same solution equals 5 mgms. of calcium carbonate. Now, if the soap solution be so made that

2·2 c.c. of it give a lather with 50 c.c. of the above barium nitrate solution, after deducting 0·2 c.c. for the amount of soap solution necessary to give a lather with 50 c.c. of distilled water, we get 2 c.c. of the soap solution to equal 50 c.c. of a barium nitrate solution, which again is equivalent to 5 mgms. of calcium carbonate, hence each cubic centimetre of the soap solution equals 2·5 mgms. of calcium carbonate. Say, for instance, a small quantity of soap solution of unknown strength has been made, and on its being standardized with 50 c.c. of the barium nitrate solution, it is found that 1 c.c. gives a lather in place of 2·2 c.c. being so required. The soap solution measures 30 c.c. Then as $1 : 2{\cdot}2 :: 30 : x = 66$; that is, the 30 c.c. must be diluted up to 66 c.c. to give a soap solution, of which 1 c.c. shall exactly equal 2·5 mgms. of calcium carbonate. Of course, if the soap solution be found too weak it must be proportionately fortified with more soap until 2·2 c.c. exactly give a lather with 50 c.c. of the 0·261 Barium nitrate solution.

To determine the Total Hardness, take 50 c.c. of the sample and place in a stoppered shaking-bottle. From a burette run in sufficient of the soap solution, until on being briskly shaken the contents of the bottle give only a faint dull sound with the formation of $\frac{1}{4}$ inch of fine uniform lather. This lather should show an unbroken surface after standing 5 minutes.

Suppose the addition of 2·4 c.c. of the soap solution have produced the necessary sound and lather. Deducting 0·2 c.c. as being necessary for the production of a lather in 50 c.c. of the purest water, we get 2·2 c.c. of the soap solution required by 50 c.c. of the water sample or 4·4 necessary for 100 c.c. Each of these cubic centimetres equals 2·5 mgms. of calcium carbonate; hence $4{\cdot}4 \times 2{\cdot}5 = 11$ mgms. of calcium carbonate in 100 c.c. of the water, representing a total hardness of 11 parts per 100,000—that is, 11° of hardness on the metrical scale. The original introducer of this soap test, Dr. Clark, used to express the hardness as so many grains per gallon, hence 11° on the metrical scale are the same as 7·7° on Clark's scale, or $11 \times 0{\cdot}7 = 7{\cdot}7$ grs. of calcium carbonate per gallon.

When the total hardness exceeds 20 parts per 100,000, an over-estimation may be made as the excess of calcium and magnesium interfere with the formation of the characteristic lather. In these cases it is better to dilute 25 c.c. of the sample with 25 c.c. of distilled water, proceed as explained, when the net amount of soap solution used will indicate the hardness in parts per 100,000.

To determine the Permanent Hardness, place 100 c.c. of the sample in a flask and boil for fifteen minutes. On allowing

to cool, all the calcium and magnesium carbonate, with most of the iron, if any be present, will form a precipitate at the bottom of the flask, but some of the magnesium carbonate will have become redissolved. This precipitate will represent the temporary hardness for the most part, while the permanent hardness will still exist in the supernatant liquid. Carefully decant this clear liquid into a measuring-glass, taking care not to shake up the precipitate. Measure it, and make up to the original bulk of 100 c.c. with distilled water. Estimate the hardness, as explained above, in 50 c.c. of it. The result will be the permanent hardness, and the difference between that and the total hardness will represent the temporary hardness.

Say, 50 c.c. of the water thus treated required 1·6 c.c. of soap solution. Deducting 0·2 c.c. for lather, we get 1·4 c.c. and $1 \cdot 4 \times 2 \cdot 5 \times 2 = 7$ mgms. of calcium carbonate present in 100 c.c. of the water, and these 7 mgms. $CaCO_3$ represent the permanent hardness of 100 c.c. (100,000 mgms.) of the water sample, or, in other words, 7 parts per 100,000 of permanent hardness.

The total hardness was 11 parts per 100,000, therefore the *temporary hardness* equals $11 - 7 = 4$ parts per 100,000.

The total hardness of a water should not exceed 30 parts per 100,000, otherwise it is unsuitable for domestic purposes. What are called hard waters vary from 20 to 30 degrees on the metrical scale, a soft water from 8 to 15, while a very soft water may contain up to 6 or 8.

The permanent hardness should not exceed 6 parts per 100,000. Of course the greater the proportion of temporary to permanent hardness, the better, since the former is, to a large extent, remediable, while the latter is not.

The Estimation of the Ammonia in a Water Sample.

This and the following analytical procedures aim essentially at obtaining evidence of organic matter in water. The organic matter may be of either animal or vegetable origin, but in every case exhibits a natural tendency to resolve itself into simple parts, more particularly into ammonia and oxidized salts of nitrogen, such as nitrites and nitrates. The process known as that of Wanklyn, Chapman, and Smith, recognizes two kinds of ammonia, namely, the *free* or *saline* ammonia, and the *albuminoid* ammonia.

The free or saline ammonia represents the ammonia combined with carbonic, nitric, and other acids, and also what may be derived from urea or other easily decomposed substances.

The albuminoid ammonia is that which can be derived from the breaking up of organic matter by the addition of a solution of strongly alkaline permanganate of potassium, and then boiling.

To estimate the ammonia in a water sample it is necessary to have the following solutions :—

(1) *Nessler's Reagent.*—This is a saturated solution of mercuric iodide in potassium iodide. It gives a yellowish tinge, with the faintest trace of ammonia, passing, if much ammonia is present, to the formation of a yellow-brown precipitate of the di-mercurammonium iodide. Nessler's solution is prepared by dissolving 35 grms. of potassium iodide in 100 c.c. of distilled water. Also dissolve 13 grms. of mercuric chloride in 700 c.c. of distilled water, and mix the two solutions. Add cold saturated solution of mercuric chloride until a precipitate of the red periodide of mercury just begins to be permanent. The liquid must then be left to cool, and may with advantage stand for a few hours before being rendered alkaline. This is done by adding 160 grms. of solid caustic potash or 120 grms. of solid caustic soda to the liquid, which is afterwards to be diluted with distilled water, so that the whole volume of the solution may equal 1 litre. In order to render the Nessler reagent sensitive, it is mixed finally with a little more cold saturated solution of corrosive sublimate, and allowed to settle.

(2) *A standard solution of Ammonium Chloride.*—Ammonium chloride, represented by the formula NH_4Cl, bears a ratio to ammonia, as represented by NH_3, of as 53·5 is to 17. Therefore if 0·03147 grm. of ammonium chloride be dissolved in 1 litre of distilled water, that solution will be equivalent to 0·01 grm. of ammonia, and 1 c.c. of this solution will equal 0·01 mgm. of ammonia.

(3) *An alkaline permanganate of potash solution* made by dissolving 200 grms. of caustic potash and 8 grms. of potassium permanganate in 1100 c.c. of distilled water, and then rapidly boiling the solution down to 1 litre or 1000 c.c.

To determine the Free Ammonia, place 250 c.c. of the water sample in a retort and connect with a condenser. Apply heat to the retort and rapidly distil over the retort contents, catching the distillate in a series of Nessler glasses. When three Nessler glasses are thus filled up to their 50 c.c. marks, a fourth is placed to catch the distillate while 1 c.c. of Nessler's reagent is added to each of the first three glasses. If these glasses be placed from left to right in the order in which they received the distillate, the yellow tint created in each of them by the reagent will show a decrease from left to right, because the first 50 c.c. collected will

contain the most free or saline ammonia, and the third the least. If there is no colour in the third or last glass, then all the ammonia will have come over. If, however, the colour is at all distinct in the third glass, a fourth must be collected and tested in the same way. As a rule, all the free ammonia comes over in the first 150 c.c. of the distillate.

The colour in the glasses is caused by the presence of ammonia, the precise amount of which we proceed to estimate in the following manner. To other Nessler glasses are added varying quantities of the standard ammonium chloride solution, each made up to 50 c.c. with distilled water and 1 c.c. of Nessler's reagent added. When a tint exactly corresponding with that given by the respective 50 c.c. of the water distillate in the presence of 1 c.c. of Nessler's solution has been obtained, the quantity of standard ammonium chloride solution added is read off. This procedure of noting and comparing tints as given by different amounts of ammonia with Nessler's reagent is called "Nesslerizing."

The presence and degree of colour must be judged always by looking down through the depth of the water in a glass placed upon a white surface. If the tint given by the first 50 c.c. of distillate be very deep or exceed the value of 3 c.c. of the standard ammonium chloride solution, it is often difficult to judge accurately its comparative value, unless it be diluted either with ammonia free distilled water or by adding it to the less deeply tinted distillates in the other glasses, note being taken of the degree of dilution made.

Suppose, for example, that from 250 c.c. of water placed in the retort, 150 c.c. of distillate were collected in three glasses, the Nessler reagent added, and the last 50 c.c. or contents of third glass are found to contain no trace of ammonia. The whole of the free ammonia in the 250 c.c. of water has therefore been collected in two Nessler glasses. Assume that it was necessary to add 2 c.c. of the standard solution of ammonium chloride to the comparison test-glass, in order to match the colour in the glass containing the first 50 c.c. of distillate, and 1 c.c. of the standard solution was needed to match the tint in the second 50 c.c. of distillate. The total amount, then, of free ammonia yielded by the 250 c.c. of water corresponds to the ammonia present in 3 c.c. of the standard solution. But, as each cubic centimetre of the standard solution contains 0·01 mgm. of ammonia, therefore 3 c.c. contain 0·03 mgm. of ammonia: this, multiplied by 0·4 or divided by 2·5, gives 0·012 mgm. of free ammonia in 100 c.c. of the sample or parts per 100,000.

To determine the Albuminoid Ammonia.—To the residue left in the retort, employed in the last process, add 25 c.c. of the

alkaline permanganate solution and 125 c.c. of ammonia free distilled water. Proceed to distill over as before, and continue to do so until no more ammonia comes over. This ammonia is the so-called albuminoid, due to the breaking up of any organic matter present in the water under the influence of an oxidizing agent in the presence of a caustic alkali. The determination of the ammonia in this case is conducted in precisely similar fashion as for the free ammonia.

Say, in this case, it is found necessary to distil over 200 c.c. in four Nessler glasses before all the ammonia had come over. Assume that the fourth glass of distillate had a colour equal to 0·5 c.c. of the standard solution, the third to 1 c.c., the second to 2 c.c., and the first to 2·5 c.c. The sum of these amounts represents that 6 c.c. of the standard solution were required to match the colour furnished by the albuminoid ammonia in 250 c.c. of water. But as each cubic centimetre of the standard solution equals 0·01 mgm. of ammonia, therefore 6 c.c. equal 0·06 mgm.; in other words, there are 0·06 mgm. of albuminoid ammonia in 250 c.c. of water, or 0·024 mgm. in 100 c.c. or parts per 100,000.

In this process, before adding the alkaline permanganate solution to the residue in the retort, it is as well to boil it (the permanganate) for five minutes in order to get rid of any traces of ammonia which may be in it.

In drinking water, the free ammonia should not exceed 0·005 per 100,000, and the albuminoid ammonia not exceed 0·01 per 100,000. The presence of much free ammonia with excess of chlorine, nitrites and nitrates, usually denotes animal pollution. Much albuminoid, with a small amount of free ammonia, indicates vegetable contamination, particularly so if the chlorides, nitrites, and nitrates are low. Rain water often contains a large amount of free ammonia, probably derived from soot, and appears to be harmless. Deep wells often show much free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would be very suggestive of sewage or at least urine.

Estimation of Nitrites in a Water Sample.

When organic matter putrefies or decomposes, it becomes reduced to its absolute elements. Of these nitrogen is one c and this combining with hydrogen forms first ammonia; the presence, more or less, of free or saline ammonia in a wa when at all polluted with organic matter, such as raw sewage. In the course of time, or as it percolates through the soil, the

ammonia in the water acquires oxygen, and gradually becomes partially oxidized to nitrous acid, HNO_2, or to nitric acid, HNO_3, which acids, by combining with bases like calcium, sodium, or potassium, form *nitrites* and *nitrates*. The oxidation of organic matter cannot go beyond the formation of nitric acid and nitrates, while the nitrous acid and nitrites mark an intermediate stage of imperfect oxidation.

The determination of nitrites and nitrates in a water is important as indicating either a pollution at some remote period with possibly dangerous matter, or more recently with a partially or completely oxidized sewage. Waters fouled by vegetable matter yield, as a rule, little nitrite or nitrate, chiefly because not only does vegetable decomposition yield relatively little nitrogen, but also because the natural tendency of all plant life is to remove both nitrites and nitrates from a water.

To determine the Nitrites, we require the following three solutions:—

(1) *Dilute sulphuric acid*, consisting of one volume of strong acid to two of distilled water.

(2) *A solution of meta-phenylenediamine*, made by dissolving 5 grms. of meta-phenylenediamine in a litre of distilled water, rendered acid with sulphuric acid. This should be decolourized, if necessary, by filtering through animal charcoal.

(3) *A milli-normal standard solution of potassium nitrite.*—Owing to the unstable nature of this salt, it is necessary to prepare it specially for making up this solution. By the following chemical equation, $\underset{154}{AgNO_2} + \underset{74{\cdot}5}{KCl} = \underset{143{\cdot}5}{AgCl} + \underset{85}{KNO_2}$, it is seen that 154 parts of pure silver nitrite in the presence of 74·5 parts of potassium chloride are decomposed with the formation of 143·5 parts of silver chloride, and 85 parts of potassium nitrite or 46 of nitrous acid as represented by NO_2. Hence, if 1·54 grms. of pure silver nitrite be dissolved in hot water, decomposed with a slight excess of potassium chloride, allowed to cool, made up to a litre, we obtain a $\frac{N}{100}$ solution of potassium nitrite, equalling 0·46 grm. of nitrous acid as NO_2. If each 100 c.c. of this solution after standing, and subsidence of the silver chloride, be again diluted up to a litre with distilled water, we get a $\frac{N}{1000}$ solution of KNO_2, equalling 0·046 grm. of NO_2, and each cubic centimetre of which equals 0·046 of a milligramme of NO_2.

The **Process** consists in placing 50 c.c. of the water sample in a Nessler glass and adding thereto 1 c.c. of both the dilute sulphuric acid and meta-phenylenediamine solutions: if an

orange colour is produced immediately, the tint will prove too deep for comparison, and another trial must be made with 25 c.c. of the water diluted up to 50 c.c. with distilled water, when probably only a faint colour will be perceived. The object of this preliminary trial is to find out the amount of water which can be used in the experiment; the proper amount is that which gives only a faint trace of colour on the addition of the reagents. Having decided the amount which can be used, it must, if less than 50 c.c., be diluted up to this amount with distilled water, and then placed in a Nessler glass. Trial glasses containing different amounts of the standard nitrite solution diluted up to 50 c.c. with distilled water are then made. One c.c. of the dilute sulphuric acid and 1 c.c. of the meta-phenylenediamine are next added to the Nessler glass containing the water to be examined and to each of the trial glasses as quickly as possible, so that the colours in them may develop from exactly the same time. The glasses are compared at the end of ten to fifteen minutes, and the amount of standard solution determined, which gives the same colour as the nitrite in the water under examination. If the tints are not matched exactly at the first time, a second attempt must be made, all the glasses being filled again at exactly the same time. The standard potassium nitrite, being of the strength of 1 c.c. = 0·046 mgm. of NO_2 or nitrogen tetroxide, the number of cubic centimetres used gives the milligrammes of NO_2 present in the sample of water. Assuming that 2 c.c. of the standard potassium nitrite are placed in a Nessler glass, made up to 50 c.c. with distilled water, receive 1 c.c. each of dilute acid and meta-phenylenediamine, and the same shade of tint obtained as that yielded by 25 c.c. of water sample after dilution to 50 c.c. and the addition of 1 c.c. each of dilute acid and meta-phenylenediamine; then $2 \times 4 \times 0·046 = 0·368$ mgm. NO_2 in 100 c.c. of water or parts per 100,000: multiplying this by $\frac{N}{NO_2}$ or $\frac{14}{46}$, we get the equivalent in terms of nitrogen.

It may be accepted as a good rule that no water which shows the presence of nitrites is fitted for domestic use.

Estimation of Nitrates in Water Sample.

A process which is both simple and satisfactory is that known as the phenol-sulphuric acid method: for it the following solutions are required:—

(1) *Phenol-sulphuric acid*, made by adding 6 grms. of pure phenol and 3 c.c. of distilled water to 37 c.c. of strong sulphuric acid free from nitrates.

(2) *Standard solution of potassium nitrate*, made by dissolving

0·0722 grm. of recently fused potassium nitrate in water, and the solution subsequently made up to a litre. One c.c. of this solution will contain 0·01 mgm. of nitrogen.

The process is thus performed: 10 c.c. of the water under examination and 10 c.c. of the standard potassium nitrate solution are evaporated separately just to dryness in two porcelain or platinum dishes. To each of the residues, 1 c.c. of the phenol-sulphuric acid is added and thoroughly mixed by means of a glass rod. If the water under examination contains a large amount of nitrates, the liquid will quickly turn red; if it contains but a small quantity, this colour will not appear for about ten minutes. After the dishes have stood from ten to fifteen minutes, their contents are washed out successively with 25 c.c. of distilled water into two clean Nessler glasses, about 20 c.c. of liquor ammoniæ (sp. gr. 0·96) added, and both made up to 100 c.c. with more distilled water.

Any nitrate present in the solutions converts the phenol-sulphuric acid into picric acid, which, by the action of the ammonium, forms ammonium picrate: this gives a yellow colour to the solution, the intensity being proportional to the amount present.

The colours of the two solutions are now compared, and the darker one diluted until the tints are adjusted, the calculation being made as explained in the preceding tests for nitrites.

Suppose 10 c.c. of the sample and 10 c.c. of the standard nitrate solution have, after treatment and dilution each to 100 c.c., given two shades of yellow, that from the standard solution being the darker. This, on dilution to 200 c.c., is still found to be too dark, but this, again on further dilution to 900 c.c., gives the desired match in colour. As the 10 c.c. of standard solution originally treated equal 0·1 mgm. of nitrogen, then $900 : 100 :: 0{\cdot}1 : x = 0{\cdot}011$ mgm. of nitrogen in 10 c.c. of the water sample, or 0·11 part of nitrogen from nitrates per 100,000. If expressed as NO_3, this equals 0·43 per 100,000.

In the case of very pure waters, it is better to evaporate down 20, 50, or more c.c. of the sample, and only 5 c.c. of the standard nitrate solution. Conversely, if the sample be rich in nitrates, it must be diluted down with distilled water.

No water used for drinking purposes should contain more than 0·35 part per 100,000 of nitrogen in the form of nitrates, unless, of course, the geological strata are such as can be legitimately regarded as the source from which the water derives these salts.

Estimation of the Oxygen Consuming Power of a Water Sample.

Although by itself of little value as a measure of the organic impurity, still the power of consuming or affinity for oxygen which a water sample has, when taken in conjunction with other analytical facts, is often a material aid in forming an opinion as to the quality of any particular water. Much of the organic matter present in water is capable of oxidation, but since the ease of oxidation bears no constant ratio to the nature of the organic matter, its estimation affords no very reliable index to the real pollution present. In all the efforts to judge the oxidizable organic matter, advantage is taken of the fact that, in the presence of organic substances, permanganate of potassium, $KMnO_4$, freely parts with its oxygen until all the permanganate has been reduced to hydrated manganese dioxide: thus, $2KMnO_4 = K_2MnO_4 + MnO_2 + O_2$: in everyday life, this change is marked by the pink colour which this salt originally gives to water being replaced by a brown. Unfortunately, different substances reduce different proportions of permanganate, and slight variations in temperature and acidity or alkalinity materially influence the readiness with which the permanganate parts with its oxygen.

To determine the Oxidizable Organic Matter, use is best made of what is known as Tidy's process. This process is based upon the chemical fact that in the presence of an acid and heat, the following decomposition of permanganate takes place:— $4KMnO_4 + 6H_2SO_4 = 2K_2SO_4 + 4MnSO_4 + 6H_2O + 5O_2$, or, in other words, 632 parts of potassium permanganate yield in the presence of sulphuric acid 160 parts of oxygen.

For Tidy's process, the following solutions are necessary:—

(1) *Standard potassium permanganate solution.*—Since 632 parts of the salt with an acid yield 160 parts of oxygen, then 0·395 grm. of potassium permanganate, if dissolved in a litre of water, will be equivalent to 0·1 grm. of oxygen. This constitutes the standard solution, and 1 c.c. of it used with acid yields 0·1 mgm. of oxygen.

(2) *Potassium iodide solution.*—A 10 per cent. solution in distilled water.

(3) *Sodium thiosulphate solution.*—One grm. dissolved in a litre of distilled water.

(4) *Starch solution.*—One grm. of starch, mixed with $\frac{1}{2}$ litre of distilled water, boiled for five minutes and filtered.

(5) *Dilute sulphuric acid*, consisting of one volume of strong acid to three of distilled water.

In performing this process, Tidy recommended two determinations to be made, namely, one of the oxygen absorbed after fifteen minutes' exposure at a temperature of 80° F., and one after four hours' exposure at the same temperature. He considered that during the first quarter of an hour, the more or less putrescent easily oxidized animal organic matters were oxidized, while the oxidation of the vegetable organic material did not take place till after four hours or so. Practically, as much information as can be gained is obtained at the end of fifteen minutes; therefore, except in special cases, the second observation after four hours is hardly necessary. If required, it is performed exactly in the same manner as the shorter exposure.

Into a stoppered bottle, capable of holding from 300 to 400 c.c., place 250 c.c. of the water sample, and heat in a water-bath to 80° F. (26°·7 C.); when the required temperature is reached, run in 10 c.c. of the dilute sulphuric acid and 10 c.c. of the permanganate solution. A pink colour will result. Maintain the bottle contents at 80° F., carefully noting whether the pink tint is discharged; if the tint disappear, add more permanganate. At the end of fifteen minutes, add to the water three drops of the iodide of potassium solution. Owing to there being a certain amount of oxygen available from the permanganate, as previously explained, this will liberate iodine from the iodide, with the result that the pink-coloured bottle contents will now become yellow: thus, $5O_2 + 20KI + 10H_2O = 20KHO + 10I_2$. The quantity of iodine set free will, of course, be dependent on the amount of potassium permanganate remaining unreduced in the water. If the iodine set free is absolutely dependent upon the amount of permanganate left unreduced by the organic matter in the water, it is obvious that any estimation of the iodine liberated will be a measure of the unused oxygen, and this deducted from what was rendered available by the original quantity of permanganate added, will give a measure of the oxidizable organic matter in the 250 c.c. of water.

We proceed to make these estimations in the following manner: To the iodine-tinted water, the thiosulphate solution is gradually added with the object of reducing it: thus, $I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$. In order to know exactly when all the free iodine has been removed from the water, an indicator in the form of 1 c.c. of the starch solution is added; this, so long as any free iodine is present, will give a blue tint. Therefore, continuing the addition of the thiosulphate, we stop the moment all the blue colour has gone, and read off the actual amount of thiosulphate used.

Unfortunately, thiosulphate of soda is a very unstable salt, and its particular value as a reducing agent needs to be judged,

at the time of each experiment, by means of a control observation of its power upon an identical quantity of permanganate in distilled water, as was used for the unknown sample. Accordingly, into a similar bottle, 250 c.c. of distilled water are placed, heated to 80° F., 10 c.c. of the dilute sulphuric acid, and exactly the same amount of permanganate as was used for the water sample added, and the whole kept at 80° F. for fifteen minutes. In this bottle, owing to there being no organic matter, practically the whole of the oxygen liberated from the permanganate under the circumstances will be unconsumed, and consequently, on the addition of three drops of potassium iodide, more iodine will be liberated, and more of the thiosulphate will be required to reduce it. The iodide, the starch, and the thiosulphate are added precisely as in the other experiment.

So soon as all the iodine has been removed, as shown by the disappearance of the blue colour, the amount of thiosulphate used is read off; its volume will represent, for the time being, the actual reducing value of the thiosulphate for the precise amount of permanganate used or added in the experiment. And the difference between the amount of thiosulphate solution needed to reduce the x amount of potassium permanganate in this pure distilled water, and that required for the same amount which has been more or less decomposed or reduced by oxidizable organic matter in the water sample, will represent the quantity of oxygen consumed by such oxidizable matter.

Example.—Say 10 c.c. of $KMnO_4$ in the distilled water has used up 40 c.c. of the thiosulphate solution; therefore 40 c.c. of the thiosulphate may be considered as equivalent to 10 c.c. of permanganate, or 1 mgm. of oxygen, because each cubic centimetre of $KMnO_4$ equals 0·1 mgm. of oxygen.

Another 10 c.c. of $KMnO_4$, in the unknown water sample, used up, say, 32 c.c. of the thiosulphate solution; therefore an amount of oxygen equivalent to the difference between 40 and 32 or 8 c.c. of the thiosulphate solution has been taken up by the organic matter. But if 40 c.c. of thiosulphate equal 1 mgm. of oxygen, then 8 c.c. equal 0·2 mgm. of oxygen. This means that 0·2 mgm. of oxygen is taken up by 250 c.c. of the water sample, or parts per 250,000; this multiplied by 0·4 equals 0·08 parts of oxygen consumed by the organic matter per 100,000.

In performing this process, the permanganate added must be sufficient to create a pink colour, which remains distinctly permanent at the end of the heating. If the four-hour test be applied, it may be necessary to make repeated additions of the permanganate solution. The *total* quantity actually used must be

carefully noted, and the same amount of course employed in the distilled water experiment.

In endeavouring to interpret the results of the oxygen process, it must be borne in mind that besides organic matter, iron salts, nitrites, and sulphuretted hydrogen will reduce permanganate of potassium, and these latter, if present, must be duly allowed for. It is difficult to distinguish between the oxygen consumed by the nitrogenous and the non-nitrogenous organic matter. Roughly speaking, the four-hour experiment gives information as to the total amount of oxidizable organic matter, while the fifteen-minutes' reaction is valuable as indicating the proportion of putrescent or readily oxidizable and presumably dangerous material. Peaty waters consume large quantities of oxygen; hence, as in all other attempts to measure the organic matter in a water sample, the results of the oxygen process must be considered in conjunction with the other analytical data and the source of the water.

In a general way, it may be said that waters of great organic purity will not consume more than 0·05 of oxygen per 100,000 in fifteen minutes at 80° F., and that when the oxygen consumed exceeds 0·1 per 100,000, the sample may be considered of doubtful purity.

Determination of Dissolved Oxygen.

This estimation in connection with the examination of waters and sewage effluents is occasionally needed, but for practical purposes the method must be simple, speedy, accurate, and not require large quantities of the sample. A further condition is that the waters must not be subjected to a diminished oxygen pressure, *i.e.* must not be operated upon in an atmosphere of inert gas, otherwise there might be a rapid loss by diffusion. Several methods for determining the dissolved oxygen in water have been proposed: the chief objection to them has been the necessity of special apparatus. As being, perhaps, the most simple and readily applied we here describe a method suggested by Winkler.

The following solutions are required for the process:—

(1) *Manganous chloride solution*, made by dissolving 80 grms. of $MnCl_2.4H_2O$ in 100 c.c. of distilled water. The solution must be free from iron.

(2) *Potassium iodide and caustic soda solution.*—Dissolve 10 grms. of iodide of potassium in 100 c.c. of a 33 per cent. solution of pure caustic soda. This solution when diluted with water and acidified with sulphuric acid ought not to give any colour with a solution of starch.

(3) *Centi-normal solution of iodine*, made by dissolving 1·27 grms. of pure dry iodine and 2 grms. of iodide of potassium in 20 c.c. of distilled water, and then making up to 1 litre with distilled water.

(4) *Centi-normal solution of thiosulphate of sodium*, made by dissolving 2·48 grms. of pure dried $Na_2S_2O_3.5H_2O$ in a litre of distilled water. This solution must be kept in the dark and in a cool place: as its value tends to alter, it should be titrated before use with the above iodine solution, diluted with water and in the presence of some starch solution; ten c.c. of the iodine solution should require 10 c.c. of the thiosulphate solution for decolourization.

(5) Starch solution as prepared for the estimation of oxygen consuming power of a water.

The **Process** is as follows: Take a glass bottle provided with a well-fitting glass stopper, and having approximately a capacity of 300 c.c. Determine accurately the capacity of the bottle. Wash out the bottle thoroughly with some of the water to be examined, and then fill it to overflowing. Introduce, by means of a graduated pipette, having a long narrow point, 1 c.c. of the iodide and sodium solution, and also 1 c.c. of the manganous chloride solution. Do this carefully and gradually, so that the point is close to the bottom of the bottle. Put in the stopper tightly, and see that no air-bubbles remain. Mix the contents by swinging the bottle lightly round; allow the precipitate which forms to settle down; if it does not readily settle, the bottle should be allowed to stand for an hour or so, but taking care that no air gains access to the bottle contents. When the precipitate has settled down and the fluid in the upper part of the bottle is clear, introduce carefully down the side, by means of a pipette, from 3 to 5 c.c. of fuming hydrochloric acid (sp. gr. 1·16 to 1·18), so as to let it fall on to the precipitate; replace stopper, and swing the bottle gently round until the precipitate dissolves. The iodine-tinted fluid in the bottle is now washed out into a clean beaker with distilled water, and then titrated in the presence of starch with the thiosulphate solution, 1 c.c. of which equals 0·0000798 grm., or 0·055825 c.c. of oxygen. The iodine liberated corresponds to the oxygen present in the water, therefore the cubic centimetres of thiosulphate used multiplied by 0·055825 give the cubic centimetres of oxygen present in the original volume of water placed in the bottle, less two or whatever volumes of the iodide and manganous solutions have been added. The various chemical reactions which take place in the process may be expressed by the following equations:—

$$2MnCl_2 + 4NaOH = 4NaCl + 2Mn(OH)_2$$
$$2Mn(OH)_2 + O + H_2O = 2Mn(OH)_3$$
$$2Mn(OH)_3 + 6HCl = 2MnCl_3 + 6H_2O$$
$$2MnCl_3 + 2KI = 2MnCl_2 + 2KCl + I_2$$

Example.—Say the capacity of the bottle was 280 c.c. After the necessary manipulations had been made, assume that 32·9 c.c. of the thiosulphate solution were used to decolourize the iodized water. This will represent 1·8366 c.c. of oxygen in 278 c.c. of water, or 6·6066 c.c. in 1 litre. A correction for temperature and pressure is not necessary.

It must be borne in mind that this process needs to be done rapidly and at once; it is also interfered with by the presence of much organic matter which absorbs the liberated iodine, and by the presence of nitrites which when acidified set free iodine. Such interference can be prevented to a great extent by working very rapidly and using as little starch as possible. The amount of dissolved oxygen in a water is influenced largely by temperature, being less in summer and greater in winter. Roscoe and Lunt give the following figures as representing the cubic centimetres of oxygen in a saturated water at different temperatures; namely, at 5° C. 8·68, at 10° C. 7·77, at 15° C. 6·96, and at 20° C. 6·28. Ordinary tap-water in this country contains on an average 7 c.c. of dissolved oxygen per litre; this is about 1 part by weight per 100,000.

Estimation of Lead in a Water Sample.

The only metal that is likely to require quantitative determination is lead. Before making this estimation, it must be first ascertained that the darkening produced by ammonium sulphide is really due to lead, not to iron or copper.

The reagents required are (1) a saturated solution of ammonium sulphide, and (2) a standard solution of lead acetate, made by dissolving 0·1831 grm. of crystallized acetate of lead, $Pb(C_2H_3O_2)_2.3H_2O$, in 1 litre of distilled water. Each cubic centimetre of this solution contains 0·1 mgm. of metallic lead.

The **Process** consists in first evaporating 200 c.c. of the water sample down to 100 c.c., and placing the same in a colour comparison or Nessler glass on white paper. Add three drops of the ammonium sulphide solution. Note if any darkening is produced. Into a similar Nessler glass put 1, 2, or more c.c. of the standard lead solution, make up to 100 c.c. with distilled water, add three drops of the ammonium sulphide solution, and match the dark colorations. Calculate the amount found in parts per 100,000, and in grains per gallon.

Thus, for example, presume water concentrated from 200 to 100 c.c. gave a colour equal to 3 c.c. of standard lead solution, with three drops of ammonium sulphide solution. Then $3 \times 0{\cdot}1 = 0{\cdot}3$ mgm. of lead in the 100 c.c. of water; but this equals or represents 200 c.c. of the original water, therefore, in each 100 c.c there are 0·15 mgm. of lead, or 0·15 cgm. in a litre (parts per 100,000); this multiplied by $0{\cdot}7 = 0{\cdot}105$ gr. per gallon, or rather more than $\frac{1}{10}$ gr. of metallic lead per gallon.

Many waters, especially those that are soft and peaty, and therefore liable to act on lead, often possess sufficient colour to equal 0·5 or even 1 c.c. of the lead solution; if this is the case, compare its colour with that produced by a given quantity of lead solution in the presence of three drops of ammonium sulphide, and make any needful deduction accordingly. Care must be taken not to clear the water by filtration, as ordinary filter-paper removes an appreciable quantity of lead.

No drinking water should contain lead, but $\frac{1}{20}$ gr. per gallon may be placed as the extreme permissible limit.

Estimation of Iron in a Water Sample.

This quantitative determination is occasionally required, and can be conveniently performed by the following process, for which these solutions are needed:—

(1) *A standard solution of ferric sulphate,* made by dissolving 0·0496 grm. of crystallized ferrous sulphate in a litre of distilled water, acidifying with sulphuric acid, and adding sufficient potassium permanganate to make a faint pink colour. One c.c. of this solution contains 0·01 mgm. of iron.

(2) *Dilute nitric acid.*—Dilute 30 c.c of pure concentrated nitric acid with distilled water to measure 100 c.c.

(3) *A solution of potassium sulpho-cyanate,* made by dissolving 15 grms. in 100 c.c. of distilled water.

The Process is as follows: Acidify 50 c.c. of the sample with 0·5 c.c. of hydrochloric acid, and add just sufficient of dilute potassium permanganate solution to convert any iron which may be present to the ferric state. Next evaporate this pink-tinted water nearly to dryness in order to drive off any excess of acid, and then dilute to its original volume of 50 c.c. with distilled water. Into each of two Nessler glasses place 5 c.c. of the dilute nitric acid and 5 c.c. of the sulpho-cyanate solution. To one of these glasses add a measured quantity of the treated water sample, and then fill both glasses up to 50 c.c. mark with distilled water. If any iron be present in the treated water sample, a blood-red colour will be produced in the glass to which a measured volume was

added. Into the other glass some of the standard iron solution is added until the colours in both agree or coincide in tint. The precise amount of the treated water sample to be added to the first glass will depend upon the quantity of iron present; but, as a rule, not more should be used than will require 2 c.c. of the standard iron solution to match it in colour, otherwise the tint produced will be too deep for accurate comparison. The subsequent calculation is obviously simple, as each cubic centimetre of iron solution represents 0·01 mgm. of iron. The result can be expressed either as parts per 100,000 or grains per gallon.

EXAMINATION OF SUSPENDED MATTER AND DEPOSIT.

Where a sediment forms from a sample of water, it is desirable to take advantage of the valuable evidence which a microscopic examination affords. The most simple method by which the deposited matter can be collected and examined is the following: After well shaking, pour from half to one litre of the sample into a large conical glass, cover it over, and set aside for twenty-four hours; then decant or siphon off as much of the supernatant water as it is safe to do without disturbing the deposited matter at the bottom of the glass. Some of this sediment should then be taken up by means of a small pipette, and transferred to several glass slides, cover glasses applied, and the examination by the microscope proceeded with, any excess of water upon the slide being removed by clean blotting-paper. The various forms of animal and vegetable life, and of inanimate organic and inorganic material, are best sought by commencing with a low-power lens, say 1 inch, and then passing on to the $\frac{1}{4}$-inch power. The steps necessary for examining the bacterial contents of a water sample are dealt with in a subsequent section.

The nature of the suspended matter varies greatly, embracing such diverse objects as mineral grit, sand, flint, chalk, and mica particles, woody fibre, fragments of leaves, starch cells, macerated paper, amorphous vegetable *débris*, hairs, feathers, down, cotton, wool, or silk fibres, and scales or wings from various insects. The foregoing are all inanimate, but in addition there is often much animate vegetable material, such as fungi, either as spores or mycelia, and numerous forms of algæ, as well as living animal forms, such as protozoa, rhizopoda, infusoria, crustacea, insects, worms and their ova or eggs. The presence of the spores and mycelia of the higher fungi indicates impurity probably derived from sewage, since the latter usually contains phosphates, without which these forms cannot live. Algæ, diatoms, and desmids are common in open wells, lakes, ponds, and streams; they are not an infrequent cause of the peculiar odour developed in such waters. The lower

forms of animal life are only found in waters containing organic matter in solution. This material may be derived from decaying vegetable matter. The higher forms of life do not necessarily denote impurity, but the presence of worms or of their ova and embryos is particularly objectionable, since they may be forms which can develop in the human body, and give rise to ill effects.

The most suspicious elements which may be detected by a microscopical examination of water sediment are those which point directly or indirectly to the waste products of man. Among the latter are cotton, wool, hair, and linen fibres, while the former include substances which leave the body in the fæces owing to their indigestibility. Under this heading may be mentioned fat cells, starch grains, muscle fibres, various connective tissue elements, shreds of membrane, epithelial cells, fragments of food, and the various parasitic worms either as ova or mature forms.

The Bacteriological Examination of Water.

No attempt is made in this section to give a complete study of this difficult and complicated question ; but merely the presentation of the more important facts, and the outline of a working scheme for the routine biological examination of waters, upon which the student, by a further study of the special literature of the subject, can build a more elaborate and complete procedure. It is also assumed that no one will attempt the bacteriological examination of a water sample who has not acquired a knowledge of the necessary experience and technique in a suitably equipped laboratory under the guidance of a competent teacher. For these reasons it is deemed unnecessary to either describe the apparatus to be found in every laboratory, or to enter into details of the comparatively simple technique used in the routine methods of bacteriological work.

We would say, however, that the bacteriological examination of a water sample constitutes an essential complement to its chemical analysis, and that the latter without the former affords at best but an imperfect gauge as to the freedom of a water from organic contamination. Bacteriological examinations of water samples are mainly undertaken either for testing the efficiency of filter-beds or for the direct detection of pollution from manure or sewage. This information upon which such opinions or conclusions can be based is practically of the following three kinds :—

(1) A quantitative estimation of the number of micro-organisms present in the sample of water under examination.

(2) The detection of micro-organisms not necessarily hurtful to

man, but whose presence and origin imply that the sample is more or less contaminated with fæcal or manurial pollution.

(3) The isolation and identification of actual disease-producing organisms. The smaller the volume of water in which the micro-organisms under the second and third headings can be detected the greater the pollution, and *vice versâ.*

Collection and Transmission of Samples.—This constitutes a very important procedure, and any carelessness displayed is liable to seriously vitiate the results. The sample should be collected in glass bottles with glass stoppers, previously sterilized at 150° C. for three hours. If sterilization by heat is not feasible, the bottles may be cleaned sufficiently by washing them out with a little pure sulphuric acid, all traces of acidity being removed by rinsing the bottle thoroughly with some of the water to be examined. In the case of rivers, ponds, or lakes, the bottle should be plunged below the surface before the stopper is removed; in this way a sample of the main body of water will be obtained. In some cases, as when the presence of the cholera organism is suspected, it is desirable to examine the surface water. If the source of water is a piped supply, the tap should be opened and the water allowed to run to waste for a few minutes before the sample is collected. It is always desirable, in the case of piped supplies, to obtain, if possible, a sample direct from the main. In the case of wells, particularly if not in constant use, it is advisable to pump continuously for a few hours before collecting the sample for examination. In all cases, after the specimen has been obtained, the glass stopper should be quickly replaced and carefully tied down with a little oiled silk. The next point is to have the sample examined as quickly after collection as possible. If the specimen cannot be examined at once, it should be packed in ice, and then transmitted to the laboratory. The importance of keeping the sample in the cold is based upon the fact that when the temperature is kept below 5° C., there is practically no increase in the number of micro-organisms in the water.

For the transmission of samples intended for bacteriological examination, special boxes or carriers are usually employed; these contain one or more glass-stoppered bottles of about eight-ounce capacity, fitting into a tin-lined receptacle, and into which they are carefully secured by a close-fitting lid. This tin case containing the bottle or bottles is surrounded by a metal receptacle for holding ice, this again being surrounded by a thick layer of asbestos and felt, the whole being contained in a strong wooden box or case having a well-adjusted, felt-lined lid, and capable of being securely fastened and locked. In transmitting these carriers to the laboratory, it is of the first importance to do so

by the most expeditious route, so as to avoid all possible delay. Full particulars as to the nature and source of the sample should invariably accompany the carrier, as without such information it is difficult to give a satisfactory opinion regarding its hygienic condition.

The Quantitative Examination.—The determination of the number of micro-organisms in a known volume of water is effected mainly by cultures on solid media, such as gelatine or agar. The method consists in adding varying quantities of the water to tubes of liquefied gelatine or agar: each of these is then thoroughly mixed and poured with suitable precautions into a sterile Petri dish, and solidified as rapidly as possible. These water-plates are then incubated, the gelatine at 20° C. and the agar at 37° C. Each organism present, capable of development under the existing conditions, develops into a mass or colony of bacteria, visible to the naked eye, and as such readily counted. The total number of colonies found gives the number of organisms capable of development in the medium used, and at the particular temperature of incubation.

The amount of water to be added to the media tubes varies with the suspected degree of pollution; for ordinary waters 0·1 to 0·5 c.c. are routine quantities to add to gelatine tubes, and from 0·5 to 1 c.c. to agar tubes. With dirty waters, these amounts will be too large, and greater dilution must be practised. For inoculating the gelatine or agar tubes before plating, 1 c.c. pipettes graduated in one-hundredths of a cubic centimetre are employed, the pipette, after thorough cleaning and plugging of the upper end with cotton wool, being carefully sterilized before use. For enumeration of the colonies, it is convenient to count with the plate on a dark background, dividing the area by lines marked on the plate itself. When plates are very crowded, it may be possible to count colonies in only a few segments, deducing the total bacterial content from these data. Apart from difficulties due to over-crowding, enumeration of colonies on gelatine plates is often impossible owing to the presence of types which more or less rapidly liquefy this medium. The same difficulty arises if working in a hot climate, or under conditions in which solidification of gelatine is impossible. In these cases the routine employment of agar for making water-plates presents advantages, as liquefaction does not take place. But it must be borne in mind that if these plates are incubated at 37° C., the majority of water organisms are suppressed, and consequently the number of resulting colonies will be much smaller than on the gelatine incubated at from 20° C. to 22° C.

In regard to the number of micro-organisms present in waters

derived from different sources, no hard-and-fast standards can be enunciated. A dirty water will contain many more organisms than a pure water, but the number in a pure supply may vary from 50 to 500 per cubic centimetre. When judging the efficiency of water filters, Koch laid down as a standard that satisfactory filtration could not be accepted if the number of micro-organisms exceeded 100 in each cubic centimetre of filtrate. As a working basis this standard is adhered to by many observers. The value and importance attaching to the enumeration of the bacteria present in a given quantity of water has been variously appraised. For our own part, we do not think that it, in itself, furnishes information of any great importance. We are forced to this conclusion from the fact that the nature of the medium, its reaction, the duration and temperature of incubation, are all important factors in the development of water bacteria. It is well known that the reaction of the media used exercises a marked influence on the number of micro-organisms which develop. Until some authoritative standard is arrived at, and all observers agree to adhere to media of that standard reaction, it is difficult to compare results. The American workers recommend all media used in this class of work to be +1·5, that is, *acid* to the extent of 1·5 per cent. of normal acid, using phenol-phthalein as the indicator. The tendency in this country is to use a +1 per cent. standard, and is the reaction usually employed by ourselves. Again, there is no uniformity of practice as to duration and temperature of incubation. Some count only the colonies visible on the second day, others those visible on the third, fourth, or even fifth days; some enumerate only colonies visible to the naked eye, others use a lens or low power of the microscope for counting. It seems desirable to be very careful about stating that a given water contains a certain number of organisms per cubic centimetre, as any accurate determination of the kind is practically impossible. The most that should be said is, to state that 1 c.c. of the sample has yielded so many organisms on such and such medium of such a reaction after so many days' incubation at a given temperature, taking care to add whether the colonies included only those visible to the naked eye, or all visible under a certain degree of magnification.

Qualitative Examination.—This embraces the isolation and enumeration of organisms not necessarily hurtful, but which from their origin are especially liable to be associated with contamination, also the isolation and identification of actual disease-producing organisms. Owing to the inherent difficulties in the way of isolating actually specific disease-producing bacteria from a water sample, it must be admitted that in the greater number of

cases we have to rely mainly upon the detection of organisms associated with fæcal or manurial contamination, and although the various methods which have been suggested for this purpose are by no means perfect or completely satisfactory, still, if properly conducted, they may be relied upon to detect pollution, even to the extent of one part of recent sewage in a million parts of water. When the pollution is less than this or when the contamination is far from recent, the bacteriological results usually suffice to raise grave suspicions of pollution, and, if supplemented by an inspection of the source of the water or a knowledge of its history, are sufficient to justify a definite opinion being formed and given. In the light of our experience, the qualitative bacterial method of examination of a water is about a thousand times more delicate than the chemical method.

A variety of procedures have been proposed for obtaining an indication of the presence or absence of organisms rarely present in waters of known purity, but which are invariably present in sewage-polluted samples. These procedures are based mainly upon the principle of either placing definite volumes of the water into media or under conditions which retard or inhibit the growth of the ordinary water organisms, and yet allow the sewage forms to develop, or placing the water sample into media which foster the growth of organisms of intestinal origin if present, rather than inhibiting the development of the ordinary water bacteria. The most practical method, in our opinion, is associated with the name of MacConkey or some modification thereof.

MacConkey's Method.

This consists in adding to varying quantities of the water sample a special medium, first suggested by MacConkey and Hill, namely, bile-salt glucose peptone litmus solution, and incubating at 42° C. for forty-eight hours. For the routine examination of waters, a concentrated stock solution should be prepared, made as follows: sodium taurocholate, 15 grms.; glucose, 15 grms.; peptone, 60 grms.; litmus solution, a sufficiency to give a deep purple tint; distilled water, 1 litre. This is boiled and filtered, and then, subject to certain dilutions as detailed hereafter, run in varying quantities into each of a number of clean test-tubes, in which also is a small inverted glass tube ($1\frac{1}{2}$ inch by from $\frac{1}{4}$ to $\frac{1}{2}$ inch). The outer tubes, after addition of the solution and plugging with cotton wool, are sterilized for fifteen minutes at 100° C. on

three successive days. The degree of dilution of this stock solution required depends absolutely upon the volume of water sample to which it is to be added, as it is desirable that in each case the final dilution may contain approximately the same proportion of the bile-salt and other constituents. For the practical application of this medium in the examination of waters, it is desirable to have the test-tubes of two sizes, namely, large ones measuring 8 inches by 1 inch, and smaller ones 6 inches long and $\frac{3}{4}$ inch in diameter. With them the following dilutions have been found to work well:—

(*a*) Into the large-sized tubes place 30 c.c. of the concentrated stock solution of bile-salt glucose peptone litmus solution, and sterilize in the usual way. To these 50 c.c. of the water to be examined may be added, and then incubated as explained.

(*b*) Dilute one volume of the concentrated stock solution with half its volume of distilled water, place 10 c.c. of this diluted solution into each smaller-sized test-tube, and sterilize. To each of these 10 c.c. of the water sample may be added, and then incubated as above.

(*c*) Dilute one volume of the concentrated stock solution with an equal volume of distilled water, place 10 c.c. of this diluted solution into each of the smaller-sized test-tubes, and sterilize. To each of these 5 c.c. of the water sample may be added, and then incubated.

(*d*) Dilute one volume of the concentrated stock solution with two volumes of distilled water, place 10 c.c. of this diluted solution into each of the smaller-sized tubes, and sterilize. Each of these may then receive 2 c.c. or less of the water under examination and be incubated.

By this method we have a series of test-tubes containing varying strengths of the bile-salt solution, and, by the addition of varying volumes of the water to be examined, so diluted that they approximately all contain the same proportions of original constituents. Experience shows that the micro-organisms which can grow in this bile-salt glucose peptone solution after incubation are divisible into three main classes, namely, (1) those which ferment the medium to the formation of both acid and gas; (2) those which produce acid, but no gas; and (3) those which produce neither acid nor gas, but merely a turbidity. Of course, if the contents of the tubes remain clear, it is evident that the micro-organisms present in the added water are incapable of growing in this particular solution; as a matter of fact, this is not infrequently the case with pure waters.

Now, what is the interpretation to be placed upon these various results? We may say, at the outset, that the organisms

which merely grow, but fail to produce either acid or gas in this medium, have little significance in the hygienic examination of water, as practically none of them can be said to be of fæcal origin. Interest, therefore, centres chiefly in the first two classes, as they are, for the most part, organisms of intestinal type, more especially those of class 1—that is, producers of both acid and gas—as these include all the more important organisms found in sewage. Moreover, as those coming under the second class—that is, producers of acid only—are invariably associated with others belonging to class 1, it is rare to find the production of acid only in this medium, the practical deduction being that it is unnecessary to examine a water sample further if, after having been manipulated and incubated as explained, it is found not to contain micro-organisms capable of producing both acid and gas in the bile-salt glucose peptone litmus solution.

The chief micro-organisms likely to be met with in a water sample, and which ferment the bile-salt glucose peptone solution, are given in the following table:—

Group I. Producing acid and gas.	Group II. Producing acid but no gas.
B. coli communis.	B. typhosus.
,, acidi lactici.	,, dysenteriæ.
,, lactis ærogenes.	,, para-dysenteriæ.
,, proteus.	,, choleræ.
,, paracoli.	,, prodigiosus.
,, paratyphosus.	Streptococci.
,, enteritidis (Gartner).	Staphylococci.
And other members of the intermediate group.	

In addition to the above-named organisms, it must be clearly understood that a certain number of micro-organisms exist in water, often of undoubted purity, which are capable of producing acid in this medium, and occasionally minute quantities of gas. This fact emphasizes the need of recognizing these reactions merely as preliminary steps in the inquiry as to the existence or absence of objectionable or hurtful types of bacteria in any given water sample, and that no hasty conclusions are to be drawn from the production of gas, and still less so from the mere acidification of the medium after inoculation with varying quantities of water. For these reasons it is imperative to continue the investigation before deciding that the water is polluted. This further investigation involves the plating out in gelatine, or upon lactose agar or any other medium suitable for the isolation and differentiation of

specific species. We deem it necessary to lay stress upon this warning, as some workers are tempted to regard these preliminary reactions as specific evidence of pollution. They certainly are not that, though in nine cases out of ten the production of acid and gas in any of the tubes is strong presumptive evidence of the presence of organisms, in the water, which have been derived from sewage or manurial matter.

Assuming, then, that one or more of the bile-salt tubes, after inoculation with the water sample, have shown acid and gas production, it is then necessary to plate out for the exact differentiation of species. This is best done by making a series of gelatine plates from the tube or tubes which have given the reaction after inoculation with the smallest volume of the water sample. The colonies which develop on the plates must then be examined, any suspicious ones fished off on to agar slopes, and from these cultures further subcultures made in the various media, to be mentioned, to establish the identity of the particular micro-organisms isolated. The various organisms liable to be found in water, capable of producing gas in glucose bile-salt solution, and consequently likely to develop on the various plates set from the original water-seeded bile-salt glucose peptone tubes, may be divided into four great groups. In the first are a number of motile organisms of a somewhat unstable biological equilibrium, which liquefy gelatine, produce gas in glucose and sucrose, but not in lactose, curdle milk very slowly, rendering it acid, and commonly produce indol in peptone solutions. These organisms represent the great *proteus* family. In the second group are motile bacteria, producing gas in glucose, lactose, mannite, and occasionally in sucrose. These curdle milk rapidly with no peptonization of the clot; they nearly always produce indol in peptone solution, but do not liquefy gelatine. They grow characteristically in both of Proskauer and Capaldi's media, producing acid in No. 1 and alkali in No. 2. These organisms are the *B. coli communis*, indifferently derived from the alimentary canal of man and animals. In the third group are non-motile bacteria, not liquefying gelatine, which not only curdle and render milk acid, but ferment sugars, other than glucose, somewhat variably. The type of this group is the *B. lactis ærogenes*. In the fourth group we find motile bacteria, fermenting glucose alone of the sugars, not liquefying gelatine and not clotting milk, but rendering it finally alkaline. These organisms are the intermediates of the colon-enteric series, and include such species as the *B. enteritidis* of Gärtner, the various para-colons and the paratyphoids. Indol production is variable with this series, but not infrequent.

It will be apparent from this summary that the liquefaction or

non-liquefaction of the gelatine constitutes a broad line of differentiation between the first group and the others; but it must be borne in mind that all the liquefying colonies on a gelatine plate prepared in this way are not necessarily members of the proteus group, though, as a matter of fact, owing to the bile-salt apparently keeping back or inhibiting the growth of the common water organisms, which are also capable of liquefying gelatine, the greater number will be found to belong to the great proteus family. Members of this group are invariably found in sewage and in dirty waters, especially where surface washings from manured land gains access to a water supply, consequently their presence in great numbers constitutes a suspicious piece of evidence. On the other hand, one occasionally meets with members of this group in undoubtedly clean and safe waters, but in these cases there is usually a complete absence of members of the other three groups; therefore, in attempting to appraise them at their proper hygienic value, one must have regard to all the facts, more particularly taking into consideration their association or non-association with members of the other groups. In the same way, it must not be hastily assumed that all the non-liquefying colonies are necessarily either *B. coli* or *B. lactis ærogenes*, or one of the various paracolons and paratyphoids: the exact determination of species can be made only by careful subculturing in a variety of media, and a critical noting of their morphology and other features. Precisely the same remarks apply to colonies which may develop on gelatine or other plates inoculated from bile-salt glucose solution, in which acid, but no gas, has formed after the addition of some of the water sample. Some of these may liquefy gelatine (*e.g.* the cholera vibrio) and some will not. Each one of the resulting colonies on these plates will need to be judged upon its individual features as manifested by subculture in various media. Probably the most reliable information will be obtained by subculture in various sugars and glucosides to observe their fermentative effects. This is particularly true of the various micro-organisms allied to the *B. coli communis*. The best media to employ for this purpose are sucrose, adonit, dulcit, and inulin. These should be made up with sugar-free peptone, bile-salt, and neutral red in accordance with the following formula: peptone 10 grammes, bile-salt 5 grammes, the particular sugar 5 grammes, water 1 litre, with 5 c.c. of a 5 per cent. solution of neutral red. Each test tube containing these sugars must contain a small fermentation tube, and the reaction considered to have taken place if acid and gas are developed; the gas production is often scanty. Each kind of sugar tube must be separately marked, and after inoculation incubated at 42° C. for 48 hours. MacConkey

suggested the division of all lactose fractors in the four following groups: 1, those which do not ferment either saccharose or dulcit; 2, those which ferment dulcit but not saccharose; 3, those which ferment both dulcit and saccharose; and 4, those which ferment saccharose but not dulcit. Of itself, this laboratory classification is of little value, unless we can say that one or other of the groups is characteristic of human or animal excreta, or better still if we can split the groups further into individual species for separate study as to their sanitary significance. MacConkey's work suggests that groups 1 and 2 are more common in human fæces, and groups 1 and 4 in animal excrement; that is in England. Speaking from personal experience, we are inclined to think that those which ferment dulcit but not saccharose are the more fæcal type, but the group is not entirely composed of these objectional varieties. Apart from fermentation tests, importance attaches to the production or non-production of indol and to what is known as the Voges-Proskauer reaction. For the indol test, it will be advisable to employ benzaldehyd, which is a mixture of the persulphate of potash and para-diethyl amido-benzeldehyd. The reaction by this reagent is far sharper and more exact than that given by the older acid method. The Voges-Proskauer reaction is obtained by growth in a medium consisting of peptone 10 grammes, glucose 5 grammes, water 1 litre. It is carried out in a fermentation tube, as in the case of the other sugars, but without any neutral red. The reaction is the slow production of a rose-red colour in the closed end of the fermentation tube, after incubating for 48 hours, on the addition of a few drops of a concentrated solution of caustic potash. The reaction may not show for quite two hours. This reaction in respect of fæcal bacteria would seem to be much neglected by routine workers.

While no detailed description can be given of all the possible microbial forms which may be met with in the bacteriological examination of water, still the following short statement, regarding the chief varieties which have a dominant significance in this branch of hygienic investigation, may be of use. The composition and mode of preparation of the various other media mentioned are detailed in the Appendix.

B. proteus.—A small bacillus with rounded ends, often in pairs or in chains: it is motile, and not spore-bearing; grows at 42° C., but better at 20° C. It stains with Gram's method. The colonies on gelatine plates after twenty-four hours are delicate granular films of irregular shape; in forty-eight hours they begin to liquefy, and appear like punched-out circles. The colonies in the early stage are usually circular; the margin may show a fine bristly forma-

tion or spindle-shaped processes tending to run out all over the gelatine. When grown as a gelatine stab culture, the medium is rapidly liquefied in a funnel-shaped manner. In broth, the growth is diffuse, without pellicle; on agar, the growth is not characteristic, being moist and greyish-white; on potato, it is moist but yellowish. In media containing glucose or sucrose there is production of both acid and gas, but in lactose there is no fermentation. In milk, clotting occurs in about two days with formation of acid, and in peptone solution there is usually production of indol after about five days.

B. lactis ærogenes.—A non-motile rod decolourizing with Gram's stain. On gelatine plates the surface colonies are porcelain white in colour, and more or less circular; the deep colonies are round, granular, and yellowish-brown in tint. On agar, the growth is opaque and porcelain white. In gelatine stab culture, the growth is free along the line of inoculation, with a nail-head expansion on the surface; the gelatine is not liquefied. In milk, there is coagulation usually within forty-eight hours, with marked production of acid. In broth, there is uniform turbidity, and not infrequently some pellicle. When grown in the various sugars, such as glucose, lactose, sucrose, maltose, and in the alcohol mannite, there is marked fermentation with gas production. In peptone and salt solution, there is usually some indol produced by the fifth day, but some strains fail to make indol. Perhaps the most characteristic cultural reaction of this micro-organism is on potato, where it produces a white creamy growth permeated with gas-bubbles. This organism is common in milk, fæces, and dirty water; it is closely allied to the *B. coli communis*, and liable to be mistaken for it unless care be taken.

B. coli communis.—This important micro-organism appears as a very short bacillus, often resembling a coccus. It is usually motile, but occasionally strains are found to be not so. As a rule, it possesses one to five flagella, but owing to their brittleness these are difficult to stain. There is no spore formation. This micro-organism stains readily with ordinary basic dyes, but is decolourized by Gram's method. On gelatine plates, the deep colonies are not unlike those of *B. lactis ærogenes*, being oval or circular in shape and brown in colour. After twenty-four to forty-eight hours, the surface colonies are thin, bluish-grey, transparent expansions with an irregular margin. Those of *B. lactis ærogenes* never show this expansive growth or the crenated margin. The ridges and surface of the *B. coli* colonies almost invariably shows tracings of furrows running from the centre to the periphery, while at times fine wavy lines parallel to the margin are to be seen. These features of the surface gelatine colonies are usually sufficient to differentiate it from the *B. lactis ærogenes*, whose surface colonies

are coarser, less expanded, and altogether lacking in that delicate mother-of-pearl-like appearance so characteristic of the common colon bacillus. The gelatine is not liquefied. As a gelatine stab, there is a nail-head-like surface expansion and marked growth along the line of inoculation. When grown as a streak on a gelatine slope, the growth is white, broad, and marked by a crenated margin. On agar, the growth is not characteristic. In broth, a general turbidity results, but usually no film or pellicle. On potato, the growth commonly takes the form of a thick brownish-yellow layer. Milk is coagulated usually within forty-eight hours after incubation at 37° C. with formation of acidity. Indol production is almost invariable in peptone and salt solution, after five days' incubation at 37° C. When grown in media containing glucose, lactose, dulcit, maltose, or mannite, there is free production of acid and gas; some few strains of this organism ferment sucrose, but in our experience the typical *B. coli communis* derived from the human intestine does not split cane-sugar, adonite or inulin, neither does it give the Voges-Proskauer reaction. When grown in the two media suggested by Proskauer and Capaldi, there is an acid growth in No. 1 after twenty-four hours' incubation at 37° C., while in No. 2 medium there is a similar growth, but the reaction is either unchanged or rendered faintly alkaline. Some writers have laid stress upon the reaction obtained with *B. coli communis* when grown in glucose-agar coloured with neutral red, when the magenta red is changed to a yellowish-green florescence after two days' incubation at 37° C. In the majority of cases this does occur, but we are indisposed to regard it as in any way specific or characteristic of this particular micro-organism. The foregoing description gives the chief characteristics of the typical *B. coli* as commonly met with in dirty water, in sewage, and from human or animal excrement, but it must be borne in mind that varieties are not uncommon which fail to conform to the type. The chief departures from the type are inability to produce indol and to bring about coagulation of milk within three or four days. We have never come across any of these aberrant forms in dirty water without finding them associated with others which conform strictly to the classic type; it is the association or not with organisms undoubtedly *B. coli communis* which must guide the worker in the formation of an opinion as to whether he has isolated a presumably fæcal organism or not.

The Intermediates.—Under this heading are embraced a number of micro-organisms which, from their cultural reactions, occupy an intermediate position between the typical *B. coli* and the *B. typhosus*. They are motile rods, staining readily with ordinary dyes, decolourizing by Gram's method, not liquefying gelatine,

and producing on that medium surface colonies which present many points of resemblance to those of the common colon bacillus. Their characteristic features are an ability to gaseously ferment glucose and maltose, make acid in mannite, failing to clot milk, but rendering it finally more or less alkaline. They invariably fail to ferment, even to the formation of acid, either lactose or sucrose. Typical members of this group are the various paracoli bacteria, the paratyphoids, the *B. psittacosis*, the *B. icteroides*, the bacillus alleged to be the cause of epidemic jaundice, and the *B. enteritidis* of Gärtner, an organism which has been associated with certain forms of diarrhœa and acute infection presumably due to contaminated or degraded meats. The occurrence of members of this group in water samples is, in our experience, rare, but an appreciation of their biological position, and as possible fermenters of bile-salt glucose broth, is necessary on the part of all those who employ this medium in the routine examination of waters.

B. typhosus.—This, the most important representative of the group which produce acid but no gas in bile-salt glucose broth, is a highly motile bacillus without spores, and decolourizing by Gram's stain. It possesses from eight to twelve long wavy flagella disposed all round the bacillus. It grows at 42° C., but better at 37° C.; it fails to do so at 0° C. It is killed by an exposure to 65° C. for ten minutes, and by an exposure of one minute to 80° C. On gelatine plates, the deep colonies are granular, and round or oval in shape. The surface colonies grow slowly, requiring seventy-two hours usually before they show their characteristic appearances as thin bluish-grey films with an irregular margin; under a low power markings are seen which look like ridges and valleys running irregularly from the centre to the periphery—in fact, these colonies resemble closely those of the *B. coli* and some other members of that group. Occasionally the surface colonies of the *B. typhosus* are without the "relief-map" appearance, and merely finely granular resembling a thin film of glass. The gelatine is not liquefied. When stabbed into gelatine, the surface growth is like the plate-surface colonies, and along the line of inoculation there is a fine growth of discrete white points or masses. If streaked on a gelatine slope, a white narrow growth develops along the line of inoculation with an irregular margin, but the whole growth is less marked than the corresponding culture of *B. coli*. The main point of distinction between the respective growths of these two micro-organisms upon gelatine is the relative slowness of development on the part of the enteric organism. On agar, the growth is not characteristic, being moist and grey. On potato, a smooth glistening film forms, which is so devoid of colour and structure as to be very difficult of detection with the naked eye. In broth, there results a diffuse

cloudiness, without pellicle. In glucose, maltose, and mannite, the *B. typhosus* produces acid but no gas, while in lactose, dulcit, and sucrose there is not even acid. After a week or more of incubation at 37° C. in peptone and salt solution there is no formation of indol. The Volges-Proskauer reaction is negative. Milk, even after a fortnight's incubation at 37° C., is unchanged to the naked eye, but there is invariably the production of some acidity. In the media suggested by Proskauer and Capaldi (see Appendix) the reaction of the *B. typhosus* is typical, namely, after twenty-four hours' incubation at 37° C. no growth in the No. 1, but a marked acid growth in the No. 2. In these reactions it will be seen this micro-organism differs markedly from the common colon bacillus. If some enteric serum is available, valuable evidence as to identity is obtainable by noting its agglutinability or not.

Closely allied to the *B. typhosus* in many of its cultural reactions is the *B. dysenteriæ* and certain associated species. From the examination of a considerable number of *B. dysenteriæ*, we are disposed to lay stress, as a means of diagnosis, upon the facts that the *B. dysenteriæ* is never so motile as the enteric organism; it further never makes acid in mannite, it does not agglutinate with an enteric serum, and, moreover, tends to produce alkalinity in milk on prolonged incubation. In all its other cultural reactions it practically is identical with those described as typical of *B. typhosus*. The various para-dysentery bacilli, or, as we prefer to call them, the *B. typhosi simulantes*, offer many points of resemblance to the enteric organism, and as they are not infrequently isolated from waters, their due discrimination is important. Judging by our own experience, these micro-organisms differ from the true *B. typhosus* only in that they fail to agglutinate with enteric sera; they are at best but feebly motile, usually produce indol, and render milk faintly alkaline. On the other hand, they stand apart from the *B. dysenteriæ*, in that they are non-pathogenic to rabbits and guinea-pigs, are not readily agglutinated with dysenteric sera, produce acid in mannite and indol in peptone and salt solution.

Apart from these, there are many organisms which present superficial resemblances to the *B. coli communis* and the *B. typhosus*, and whose isolation from water samples may give rise to difficulties. The more common are the atypical members of the coli group, reference to which has been made already. The *B. acidi lactici* produces surface colonies somewhat like those of the enteric and colon bacilli; but it is a spore-bearing organism, coagulating milk, producing indol, and forming gas in glucose media. Another micro-organism which may give trouble is the

B. ureæ, and occasionally found in dirty water. Its surface colonies on gelatine are of the colon-enteric type, but it does not react to either typhoid or dysenteric sera, and rapidly converts urea into ammonium carbonate. The *B. sulcatus* is a common water organism which occasionally is mistaken for both *B. coli* and *B. typhosus* on gelatine plates in their early stage. It can usually be recognized by the fact that the colonies acquire a yellow colour. Their subcultures are readily distinguished by the facts of not coagulating milk, producing no indol, and forming no gas in glucose. Similar difficulties may arise with another

Name or number of Organism.	Motility.	Gram negative.	Liquefies gelatine.	Ferments. Lactose.	Ferments. Sucrose.	Ferments. Dulcit.	Ferments. Adonit.	Ferments. Inulin.	Gives Indol.	Gives Voges-Proskauer reaction.
B. coli communis	+	+	−	+	−	+	−	−	+	−
B. acidi lactici	−	+	−	+	−	−	+	−	+	−
B. lactis aerogenes	−	+	−	+	+	−	+	−	−	+
B. cloaca	+	+	+	+	+	−	−	−	−	+
B. proteus	−	−	+	−	+	−	−	−	+	−
B. sulcatus (Gunthal)	+	+	−	+	−	−	−	−	+	−
Oxytrens perniciosus	−	+	+	+	+	+	+	+	+	+
B. coscroba	−	+	−	+	+	−	−	−	+	−
B. typhosus	+	+	−	−	−	−	−	−	−	−
B. paratyphosus	+	+	−	−	−	+	−	−	−	−
B. dysenteriæ	+	+	−	−	−	−	−	−	−	−
B. paradysenteriæ	+	+	−	−	−	−	−	+	−	−

common water organism, namely, the *B. fluorescens non-liquefaciens*, but its fluorescence is characteristic, it produces no gas in the various sugars, and does not coagulate milk. Another micro-organism frequently present in water is *B. lactis ærogenes*. This is a gram negative rod, non-motile, does not liquefy gelatine, ferments lactose, sucrose, and adonit, but does not affect dulcit or inulin. It gives no indol, but does give a Voges-Proskauer reaction. The possible presence of this and other similar micro-organisms in a series of plates set from a water culture should be borne in mind: in no case should an opinion as to identity be formed hastily or from an examination of a

mere surface or other colony; each suggestive colony must be fished off on to an agar slope, and the final judgment found only upon a critical analysis of the subcultural reactions in various media.

For the differentiation of various micro-organisms the table on p. 120 may be found useful. It can be extended indefinitely as many organisms found in water are as yet unnamed. It is convenient in practical work to give them a simple serial number.

The **Spirillum choleræ** is an important organism to those engaged in examining water supplies in tropical countries. It is a small curved micro-organism resembling a comma, usually only one curve is seen, but sometimes two spirilla are attached ends on, and an S-shape produced. It is very motile, having a single flagellum at one end. It does not form spores, but degraded or involution forms are not uncommon, when it appears short and thick like a large coccus. It is markedly ærobic, and grows best at 37° C. The colonies on gelatine plates, in twenty-four to forty-eight hours, appear as minute white points, which under a low power show an irregular margin. Later liquefaction of the gelatine occurs. If grown as a gelatine stab, well marked liquefaction is seen on third day as a funnel-like depression. The growth on an agar slope is not characteristic, but on agar plates the surface colonies appear under a low power as very transparent brownish-yellow circular discs. In broth there is diffuse turbidity with a thin pellicle on the surface. Milk remains unchanged; the growth on potato is not characteristic. Indol and nitrite production is rapid and marked in peptone and salt solution, requiring only the addition of a few drops of pure sulphuric acid to show the so-called "cholera red" reaction. There is no production of gas in the sugar media, but acid is formed in glucose. If a cholera serum is available, agglutination of this spirillum is marked in dilutions from 1–10 to 1–120.

The difficulties of diagnosing the true cholera spirilla in water are often great, and mainly owing to the fact that large numbers of other spirilla may be present which are not necessarily pathogenic. The following is the simplest and most practicable method for the isolation of the cholera spirillum from a water sample. It is based upon the fact that the optimum medium for the growth of the organism is one containing 1 per cent. of peptone and 0·5 per cent. of salt, and really consists in converting as much of the suspected water as possible into such a solution, incubating at 37° C. for a few hours, and if the spirilla are present isolating them from it. The technique suggested is to make a strong or stock solution containing 10 per cent. of peptone and 5 per cent.

of salt; add 10 c.c. of this solution to 90 c.c. of the water sample in a sterile flask, and then incubate for from fourteen to twenty hours at 37° C. If cholera spirilla are present they will be found in the scum or pellicle which forms on the surface of the water. Loopfuls from this surface water should be removed and plated out in gelatine or smeared over the surface of solidified agar in a series of Petri dishes. These must then be incubated for another twenty-four hours, and carefully examined for colonies of the suspected spirillum; any suggestive colonies must be subcultured and judged by their resulting reactions.

Streptococci.—The hygienic significance to be attached to the presence of these micro-organisms in water has been much debated. They undoubtedly are present in large numbers in all sewage, and can be found, too, if searched for, in the majority of polluted waters. Owing to their minuteness, the delicacy of their colonies, and the not infrequently large volumes of water which must be concentrated for their detection, the routine search for these micro-organisms is the exception rather than the rule in the bacterial examination of water samples. We are disposed to think that this neglect of noting the presence or absence of streptococci is unwise, as although the presence of streptococci alone cannot be considered as indicating necessarily a dangerous contamination, still, in view of the fact that these organisms tend to rapidly disappear in dilutions of old sewage, their presence in a water supply indicates a recent contamination, but unless they are accompanied by the presence of *B. coli* this contamination is not necessarily dangerous. On the other hand, their absence does not of itself imply purity and safety; while their presence, at all events in any number, even in the absence of *B. coli* and other fæcal organisms, is evidence highly suggestive of doubt as to the fitness of a given sample for domestic use, and should be a signal for a more critical inquiry into the circumstances.

The streptococci are small or medium-sized cocci arranged in chains of varying length. They stain with the basic dyes and also by Gram's method. The greater number of strains which we have isolated from sewage and sewage-polluted waters do not liquefy gelatine, but a few varieties do so. On gelatine plates, the surface colonies are granular, circular, and extremely small, with a clear sharp edge, but a few present streaming projections from the margin. In broth, the resulting growth is generally diffuse. Milk is clotted usually by the third day. In peptone and salt solution indol is produced. Glucose and lactose media are acidified, but there is no gas formation. On potato and on agar, the growths are not characteristic. In bile-salt glucose

broth, there is usually a definite production of acid without gas. Although these are the cultural features of the greater number of strains which have come under notice, it must be borne in mind that certain varieties do not conform absolutely to these reactions, the more notable exceptions being an ability to liquefy gelatine and a tendency to form clumps like staphylococci rather than chains. For the isolation of streptococci from water, the concentration of not less than 500 c.c. to 10 c.c. by filtration through a sterile bougie, and subsequent plating in gelatine or on agar, probably constitutes the most satisfactory technique.

The Significance and Detection of the B. Enteritidis Sporogenes of Klein.

Since Klein first described this micro-organism as being found in all sewages, dirty waters, horse-dung, and earth from manured fields, its presence in or absence from water samples has been deemed a matter of importance. It is an obligatory anærobic bacillus of considerable size, of variable mobility, staining by Gram's method, and producing under certain conditions oval spores situated in the middle of the rods. On solidified serum it grows well at 37° C., the serum being gradually liquefied, and spores forming about the third day. It grows well also in glucose agar, splitting and tearing up the medium by a copious formation of gas-bubbles. It grows in much the same way in glucose gelatine, slowly liquefying the gelatine. On the surface of an agar slope, the colonies are grey, flat expansions, having no crenations, and the individual bacilli producing no spores. When grown in milk, there is a rapid separation of acid whey and flocculi of casein, much gas formation with a distinct smell of butyric acid. No spores are produced in milk. The separated whey swarms with the bacilli, and is actively virulent if injected into rodents.

The hygienic significance to be attached to this micro-organism has been much debated. Our experience indicates it to be invariably present in horse-dung, street-sweepings, manure from fields, and in most sewages. Its detection in undoubtedly dirty and sewage-polluted waters is not constant, so much so that we are disposed to doubt whether its importance, as an indicator of sewage in water samples, has not been overrated. Many of the discrepancies as to this micro-organism appear to be due to the fact that there are two other organisms in constant association with filth and decomposing animal matter which present marked resemblances to the *B. enteritidis sporogenes* of Klein, and with which it seems to have been confused; these are the *B. butyricus*

of Botkin and the *B. cadaveris sporogenes*. The following table (given by Klein) shows the essential difference between these three anærobic bacilli :—

B. enteritidis sporogenes.	B. butyricus.	B. cadaveris sporogenes.
Broad cylindrical rods, staining with Gram; some motile.	Same as *B. enteritidis sporogenes*.	Cylindrical, thin, thread-like rods; very motile; staining with Gram.
Oval spores situated in the middle of rods.	Same as *B. enteritidis sporogenes*.	Oval spores situated at end of the rods, drum-stick like.
Grows well on gelatine, which it slowly liquefies.	Does not liquefy gelatine, but grows as a mass of convoluted threads.	Liquefies gelatine rapidly, emitting a putrid odour. Free spore formation.
As a stab in gelatine, spherical colonies appear with no filamentous projections. Slow liquefaction.	As a stab in gelatine, spherical colonies with horizontal filamentous projections. No liquefaction.	As a stab in gelatine, rapid liquefaction with putrid odour.
On an agar surface, gives circular flat colonies. No spore formation.	On an agar surface, grey flat colonies with crenated edge. No spores.	On an agar surface, thready, branched colonies, rapidly forming spores.
As a stab in agar, little tendency to form lateral branching. Much gas, no spores.	As a stab in agar, characteristic bundles of threads project laterally in the depth. Much gas, no spores.	As a stab in agar, free growth of threads along the stab. Much gas, rapid spore formation.
In milk there is a rapid separation of acid whey and flocculi of casein. Much gas, no spores, but marked smell of butyric acid.	Same as *B. enteritidis sporogenes*.	In milk, much gas formed, also rapid spore formation; the milk is slowly decomposed.
On serum, free growth with slow liquefaction. Spores are formed.	On serum, grows well, very slow softening.	On serum, rapid liquefaction, with putrid odour and free spore formation.
Injected into rodents. Very virulent.	Not pathogenic to rodents.	Not pathogenic to rodents.

Experience indicates that, unless care is exercised, it is easy to confuse these micro-organisms one with the other, especially if too much reliance is placed upon the milk reaction. Unless an organism gives all the reactions, particularly that of pathogenicity, it should not be called the *B. enteritidis sporogenes*, but for practical purposes of water analysis it appears sufficient to identify any one of these three anærobic bacilli, as the presence of any one of them is significant of pollution. As these spore-bearing organisms occur rarely in large numbers in even dirty waters, the bacterial

contents of a fairly large volume of the water sample should be used for their detection. This should be about 500 c.c., which must be filtered through a sterile bougie, the organisms arrested on the surface of the filter being then brushed by means of a sterile brush into 10 c.c. of sterile water. Varying proportions of this must be then transferred to tubes of recently boiled sterile milk, the temperature of which at time of inoculation should not exceed 80° C., and then grown anærobically. The portions may be conveniently distributed into three milk tubes, namely, 6 c.c. into one, and the remaining 4 c.c. equally into two others. Some melted vaseline is then poured over the surface of the milk, in order to exclude air by formation of a covering some half inch in depth. The milk tubes are then placed in a water-bath at 80° C. for twenty minutes, cooled until the vaseline is well set, and finally incubated at 37° C. for three days. If any of these anærobic bacilli are present, the typical changes in the milk tubes will be produced. If no result is produced in any of the three tubes inoculated, the water sample may be said to contain less than one spore per 500 c.c.; if the typical change occur in the one which received the 6 c.c. of filter brushing, but not in the other two, the water is assumed to contain less than one spore per 100 c.c., but one or more in 300 c.c. If the typical change occurs in one or both the other tubes, there is probably one or more spores in each 100 c.c. of the sample. If the milk reaction is so atypical as to raise doubts as to whether the organism present is really the *B. enteritidis sporogenes*, but rather one of its allies, the point can only be settled by careful subculture on the lines indicated. We have never detected any of these anærobic micro-organisms in a water sample, without finding concurrent evidence of the *B. coli* and other fæcal forms.

The Interpretation of the Results of a Water Analysis.—This often offers undoubted difficulties, especially to the student and others depending exclusively upon the results of a chemical analysis. The reasons for this are twofold: (1) at best the indications given by the chemical examination are only relative, as the results obtained cannot be interpreted correctly except by reference to local standards; (2) between an undoubtedly good water and an undoubtedly dirty water there is a considerable range of waters whose chemical analytical features are very ambiguous. There is no general standard which can be fixed for all waters; the source and its immediate surroundings must be known before a reliable opinion as to the quality of the water can be given. What we need is a carefully constructed series of water standards for individual areas or districts. These standards should relate not only to chemical constituents but to bacterial contents. These

standards would be of great value in respect of surface waters, where any serious departure from the average would at once suggest cause for critical inquiry as to the why and wherefore. In the absence, then, of district standards or averages, what can be done? We can depend only upon the following procedures, which we place in their order of value: (1) a careful local inspection for any source of possible pollution; (2) a bacteriological examination made as soon as possible after collection of the sample; (3) a chemical analysis. It is rare for a sample of water to yield doubtful results under either the second or third heads when the report under the first has been carefully obtained and found to be free from suggestive features. We, therefore, attach the greatest importance to this matter of local inspection, feeling sure that if carefully and intelligently carried out it affords information of the greatest value.

In the preceding pages an attempt has been made to show on what lines a bacterial examination of a water sample should be conducted, and the probable results likely to be obtained in the case of clean and dirty waters respectively. We are indisposed to lay down numerical standards as to the presence of individual bacterial forms in waters: such we know have been formulated, but, in our opinion, they are apt to be used in too routine a manner. Each individual water sample must be judged on its merits with due regard to all the facts. While it is difficult to conceive a properly constructed deep well, and apparently remote from sewage pollution, yielding a water containing any fæcal micro-organisms, no matter how large a volume were carefully examined, it involves less imagination to account for the presence of such forms in comparatively small amounts of surface water, such as are obtained from lakes, ponds, rivers, or shallow wells imperfectly protected. Loath as we are to lay down any arbitrary standard, still for the student and inexperienced we know that this negative attitude is unsatisfactory. Therefore if we express any opinion it is merely as a guide. In this sense we are disposed to say, that the total count on gelatine from a deep-well water sample should not exceed 100 colonies to the c.c. In upland surface and shallow wells, we place the margin of safety at 500 per c.c. But in all these cases the gelatine count should be read in conjunction with the agar plate count at 37° C. The latter should not be more than one-tenth of the former in a safe water. In cases where the agar plates, after incubation at blood heat, are sterile, or nearly so, a deep-well water yielding from 500 to 1000 colonies on gelatine might be passed with confidence. The following empirical scheme may be taken as a working guide:—

I. Impure or Sewage-tainted Waters.

Gelatine plates.—Innumerable colonies, nearly all liquefying, unpleasant odour.

Agar plates.—Innumerable colonies, chiefly small and grey coloured.

II. Dirty or Doubtful Water.

Gelatine plates.—At least 500 colonies to the c.c., chiefly liquefying.

Agar plates.—About one-tenth found on gelatine.

III. Clean or Safe Water.

Gelatine plates.—Few colonies or many, few liquefying types, chromogenic type common.

Agar plates.—Sterile, or nearly so.

With regard to the number of *B. coli communis* that may be permitted or expected to exist in good potable water, we would say, one per c.c. in upland-surface water and waters from shallow wells. In the case of deep wells, say, one per 10 c.c. It must be understood that *B. coli communis* is much commoner in rural districts than many think, especially in surface waters. The significance under these circumstances is not so great as in the case of wells. Great care must be taken that the isolated organism is the true *B. coli communis*, and that an error is not made through the presence of other lactose fermentors of quite a distinct nature. As to the chemical results, we would say no more than that the evidence of present or recent animal pollution is especially suggested by high chlorides and oxidized nitrogen in association with marked free and albuminoid ammonia; that of past or remote animal pollution by high chlorides and oxidized nitrogen (not explicable as derived from geological strata) with generally little free and albuminoid ammonia. If the fouling is chiefly of vegetable origin, we may expect to find high figures for albuminoid ammonia and oxygen absorbed in association with low figures for chlorides and oxidised salts of nitrogen. Beyond this general statement we are not prepared to dogmatize; it may be asked, what constitutes a high figure in respect of these various constituents? The line of demarcation in each case may be taken for practical purposes at the figures already given when explaining the respective analytical procedures advocated.

As typical of actual analytical results, a few examples of waters from different sources, with expressions of opinion upon them, are given in the following table:—

ANALYSIS OF WATERS, EXPRESSED IN PARTS PER 100,000.

Source and circumstances.	Chlorides.	Nitric and nitrous nitrogen.	Nitrites.	Free ammonia.	Albuminoid ammonia.	Oxygen absorbed.	Bacteriological results.	Opinion.
1. Shallow well, risk of sewage from blocked drain suspected	12·5	1·5	traces	0·005	0·006	0·15	B. coli found	Unsafe.
2. Spring, close to a ditch liable to overflow	4·0	1·7	nil	nil	0·006	0·20	Sewage organisms present	Unsafe.
3. Deep well, coping, cover, and steining defective	29·0	0·11	nil	0·055	0·002	0·11	Sewage organisms present	Polluted and unsafe.
4. Deep well, well protected	2·8	0·03	nil	0·010	0·004	0·06	No sewage forms present	Safe.
5. Shallow well, apparently well protected	2·2	0·002	nil	0·011	0·009	0·2	No sewage forms found	Doubtful; unsatisfactory.
6. Surface water from moor, well policed	1·0	0·16	nil	0·003	0·012	0·290	No sewage forms found	Safe.
7. Spring, well protected	3·0	0·6	nil	0·009	0·006	0·122	No sewage forms found	Safe.
8. Deep well in farmyard	19·0	0·39	traces	0·018	0·004	0·110	Sewage forms found	Unsafe; polluted.
9. Shallow well in farmyard	1·0	0·8	nil	nil	0·003	0·040	No sewage forms found	Safe.
10. Spring in pasture field, not well guarded; ditch near, liable to overflow	3·9	0·2	nil	0·008	0·03	0·180	Sewage organisms found	Unsafe and polluted.
11. Deep well, protected	22·0	0·09	nil	0·011	0·004	0·060	No sewage forms found	Safe.
12. Spring in a copse, no protection	1·6	1·1	nil	0·02	0·001	0·015	No sewage forms found	Unsafe.

CHAPTER III.

FOOD.

The Classification, Nature, and Uses of Food Stuffs.—We may define the word *food* as including everything we take into our bodies which either directly or indirectly goes to the growth and repair of the body or to the production of energy or functional activity in any form. This definition necessarily includes not only all the ordinary articles consumed in eating and drinking, but also water and air. Since, however, the taking in of air into our lungs is mainly an involuntary act, it is customary not to include air and its constituents taken into our bodies by the lungs as foods, but to strictly limit the term *food* to substances taken by the mouth into the digestive tract.

It is convenient to speak of the various substances which constitute food as *proximate principles*, because, consisting as they do of carbon, hydrogen, oxygen, and nitrogen, combined more or less into highly complex bodies, they really are elementary constituents or proximate principles of the human organism. These elementary or proximate principles may be conveniently classified as follows:—

1. Proteins.
2. Fats.
3. Carbohydrates.
4. Mineral salts.
5. Vegetable acids.
6. Vitamines or accessory principles.

The simplest division of the various constituents of food is into the nitrogenous and the non-nitrogenous, or those which contain nitrogen and those which do not. The proteins alone contain nitrogen; but it is possible and probable that the vitamines have also a nitrogen basis. The greater part of our body is made up of nitrogen containing substances. A large amount of nitrogen in the form of urea, uric acid, and other substances, is being lost daily from our bodies by the urine; and to repair this loss, a daily intake of nitrogenous food is required. The only form of nitrogen food which the body can make use of is protein, with the vitamines as accessory agents. The nitrogenous content of the vitamines is at present not known. A plant equally needs nitrogen, but this it obtains from the ammonia

and nitrates of the soil, which are much simpler bodies than proteins.

All proteins are composed of carbon, hydrogen, oxygen, nitrogen, and sulphur, with occasionally a little phosphorus. Their general percentage composition may be taken as being: nitrogen, 16 parts; carbon, 54 parts; oxygen, 22 parts; hydrogen, 7 parts; and sulphur, 1 part. The proteins, when regarded as foods, are divisible into two great groups, according to their nutritive value. The more nutritious one is the group of true proteins, consisting of albumin, myosin, glutin, casein, legumin, and peptones; in them, the proportion of nitrogen to carbon is nearly as 2 is to 7. The other, or less nutritious, group is sometimes called the albuminoid group; its members include substances obtained only from animals, such as gelatin, chondrin, ossein, and keratin; in them, the proportion of nitrogen to carbon is as 2 is to $5\frac{1}{2}$.

Albumin constitutes the essential constituent of that substance which, called by physiologists protoplasm, really is the physical basis of life. In its most familiar form, we find it as egg albumin, or that which makes up nearly the whole of the white and a third of the yolk of an egg. A similar body is serum albumin, or the chief solid constituent of blood serum.

Myosin, or muscle albumin, is present largely in muscle, from which it can be obtained by first washing out all the serum, then dissolving the mass in a 10-per-cent. solution of common salt, and dropping the semi-solid substance into a vessel containing distilled water, in which it forms a flocculent deposit.

Glutin is an insoluble protein obtained from the seeds of most of the cereals. If a little flour be placed in a piece of muslin and a stream of water be allowed to run on it, as the water leaves the paste it will be quite milky, and if collected, the white powder which makes it milky will settle at the bottom of the vessel. The powder thus obtained from the flour is starch. The substance which remains in the muslin is not at all like flour or dough, but is a sticky substance, and is really nearly pure glutin.

The three foregoing substances have one common feature, namely, that they are coagulated by heat; and when so coagulated, as in cooking, they are not dissolved by either water or dilute acids and alkalies, but are readily dissolved and digested by the gastric juice of the stomach.

Casein is the nitrogenous solid present in milk, familiar to us all as the curd which forms when an acid is added to milk

Legumin is a protein very much resembling casein, but present chiefly in the seeds of beans and peas.

Peptones and *albumoses* are forms of proteins very closely

related one to another, and though probably widely distributed in vegetables and plants, are chiefly formed by the action of pepsin upon ordinary proteins. The albumoses are, strictly speaking, precursors or bodies formed before peptones during digestion of proteins. The peptones are remarkable for their extreme diffusibility and ready absorption by the alimentary canal. Owing to their easiness of digestion, these forms of protein are now largely given in the various kinds of partly artificially digested foods for the sick, though it must be remembered that they do not possess the same nutritive value as the ordinary proteins of food. Both casein and the peptones have the common characteristic of not being coagulated by heat.

As closely allied to the foregoing may be mentioned *syntonin*, or acid albumin, which exists in some meats, and also *alkali albumin*. These are formed by the action of dilute acids and alkalies on the ordinary proteins, and are not precipitated from solutions by boiling.

The albuminoids, such as gelatin, chondrin, etc., are bodies closely resembling the albumins, but probably not existing as such in the tissues of the body, but only obtained from them by prolonged boiling. These bodies are easily dissolved in hot water, and yield more or less the same products after digestion as the proteins, but experience shows that life cannot be sustained when this is the only nitrogenous matter taken as food.

For practical purposes, it can be said that the nutrition of the nitrogen containing tissues means the nutrition of the body, and that the main part of the protein substances taken in as food is, at least for a time, stored up in the body generally, to be used up as required by the tissues for their repair and growth, and, in a limited sense, also as a source of some of the fat of the body and of the glycogen found in the muscles and liver; any excess over these needs being at once metabolized and eliminated. From this it is evident that the proper supply of the protein food stuffs is of the first importance, though an excess of protein food throws an excess of work on the nitrogenous tissues. The natural law seems to be that to preserve health the nitrogen taken must equal that destroyed.

Fats.—These contain carbon, hydrogen, and oxygen, but no nitrogen. The proportion of oxygen in them, however, is insufficient to combine with all the hydrogen present so as to form water. When taken as food, the fats not only repair or renew the fatty tissues, but yield energy and heat, owing to their oxidation into carbon dioxide and water. In addition to this, they help in the proper digestion of the other foods, possibly owing to their power or influence in promoting the flow of bile and

the pancreatic juice. When consumed as food, the fats are not acted upon by either the saliva in the mouth or by the gastric juice of the stomach, but reach the small intestine more or less unchanged, where they become emulsified by the bile and pancreatic juice, and in the emulsified state are readily absorbed by the lacteal vessels. Fats are found in the majority of diets of all nations, and by those living in very cold countries, the amount consumed is very large. When hard work is being performed, an increase of fatty food is demanded.

Carbohydrates.—This is a large group, and embraces all the various starches and sugar, also cellulose and gum. Like the fats, these contain no nitrogen, but only carbon, hydrogen, and oxygen; these two latter elements exist in sufficient proportion to form water, hence their name, "carbohydrates." In the main, the carbohydrates are derived from the vegetable world, though lactose, a kind of sugar, is found in milk, and glycogen, a form of starch, exists in the liver.

The *starches* represent a large class of foods, and constitute the chief portion of the seeds of the various cereals and potatoes. Starch combines with iodine to form a blue colour, constituting thereby a simple test for its presence. In cold water or alcohol, starch is insoluble, but at about 180° F. water causes the granules to burst and swell out. Heat and dilute acids convert starch into a gum-like substance, called dextrine, and, if carried further, into grape sugar. A similar action is produced upon starch by the saliva and pancreatic juice. Starch, represented by the formula $C_6H_{10}O_5$ under the influence of these juices, takes up a molecule of water H_2O and becomes $C_6H_{12}O_6$, or grape sugar; this, on being taken up by the blood, is carried along the portal vein to the liver, where it is transformed into glycogen or liver starch, to be subsequently supplied to the system as the needs of the body demand. When exposed to the action of diastase, which is a peculiar ferment existing in all germinating seeds during growth (malted barley, for example), starch is converted into another form of sugar called maltose, $C_{12}H_{22}O_{11},H_2O$, a substance isomeric with lactose.

The sugars belong practically to one or other of two kinds, namely, the sucrose or cane-sugar variety, and the glucose or grape sugars.

Cane sugar, or *sucrose*, is the ordinary sugar of commerce, extracted chiefly from sugar cane. It is a crystalline body, not soluble in either absolute alcohol or ether, though freely so in weak alcohol; in water, its solution is thick and syrupy. Cane sugar is represented by the formula $C_{12}H_{22}O_{11}$, and to its group belong *maltose* and *lactose*. The former is a low form of sugar,

the final product of the action of diastase on starch. Lactose, $C_{12}H_{24}O_{12}$, or sugar of milk, is a variety of sugar found only in the milk of the mammalia. It is only partially soluble in either hot or cold water, and not directly susceptible of alcoholic fermentation except under the action of weak acids which convert it into grape sugar. In the presence of any decomposing proteins, lactose is transformed into lactic acid. One of the most remarkable features connected with the sugars is their power of deflecting a ray of polarized light to either the right or left. Cane sugar has a specific rotating power of $73^\circ{\cdot}8$ to the right; maltose has a similar power of 155° to the right; while lactose has an action on polarized light in the same direction of $61^\circ{\cdot}5$.

Grape sugar, or *glucose*, also called dextrose, or starch sugar, exists ready formed in grapes and other fruits, but is also made on a large scale from starches either by treating them with dilute acids or by the action of malt; in fact, grape sugar is the first product during the fermentation of either cane sugar, milk sugar, or starch. When a solution of cane sugar is boiled with dilute mineral acids, the sugar is split up into two glucoses. One of these rotates polarized light to the right, and is hence called dextrose; the other rotates it to the left, and hence called levulose. This mixture of dextrose and levulose is often called invert sugar, because the polarization of light is the opposite of that of cane sugar, for although dextrose or glucose rotates to the right some $57^\circ{\cdot}6$, and levulose to the left, yet the latter rotates so much more, namely, $108^\circ{\cdot}8$, that the combined solution polarizes distinctly to the left. Glucose or dextrose is soluble in both water and dilute alcohol, and is directly broken up or fermented by yeast into alcohol and carbon dioxide.

Among carbohydrates must be included cellulose and pectose. *Cellulose* constitutes the chief framework of plants; it is quite insoluble, and without any dietetic value. In a similar way, *Pectose*, or vegetable jelly, is found in various ripe fruits, being really a later stage of the insoluble body present in most unripe fruits, and known as pectin. Its precise composition is unknown.

In their physiological use, the carbohydrates closely resemble the fats and oils; being directly used in contributing to the maintenance of animal heat and the production of force or energy as well as the formation of fat. They, however, differ from the fats in that the amount of them consumed as food is proportional to the quantity of CO_2 excreted; with fats this is not so. Performing as they do in the body similar functions, it has been surmised that fats and carbohydrates might be mutually interchangeable as articles of diet. On this point, although the evidence is not very precise, the general consensus

of opinion is that they are not wholly interchangeable, though perhaps practically so, as instanced by the fact that, owing to their relative cheapness, carbohydrates largely replace, but not completely, the fats in the diets of the poor. A certain degree of health can be maintained on a diet of proteins, fats, salts, and water, but the absolute withdrawal of fats and a bare substitution of carbohydrates for them rapidly leads to a loss of vigour and health. The truth probably lies in the acceptance of an admixture of both fats and carbohydrates in the diet.

Mineral Salts.—Among the mineral salts which constitute a part of the proximate principles of food must be included chloride of sodium or common salt, the phosphates of lime, potash, soda, and magnesium, along with small quantities of sulphates, and possibly iron. These, in their various and respective ways, are essential for the repair and growth of all parts of the body. The uses of the chlorides, as typified by common salt, are very important. The complete withholding of ordinary salt from food leads to rapid disease, and even death. The chlorides generally keep in solution the globulins of the blood and other fluids, while at the same time are the source of the hydrochloric acid of the gastric juice, and materially aid in the solution of albumin. The phosphates of lime, potash, and magnesia contribute, especially in the young, to the formation of bone; while iron forms an important part of the hæmoglobin of the red blood corpuscles.

If we remember that 64 per cent. of the body consists of *water*, the need of it is not difficult to understand. Though a portion of it is obtained by the oxidation of the hydrogen in the tissues, still the greater part is derived from that taken in as food. In the body itself, water serves chiefly for the solution and conveyance of food to different parts of the system, for the excretion of effete products, for the equalization of heat by evaporation, both from the lungs and skin, as well as for the regulation of all the chemical and mechanical functions of the body.

Vegetable Acids.—These, though not strictly speaking foods, play so important a part in preserving the health of man that they demand some considerable notice. The chief among them are tartaric, citric, malic, oxalic, and acetic acids. *Tartaric acid*, $C_4H_6O_6$, exists largely in grape juice chiefly as the acid tartrate of potassium; *Citric acid*, $C_6H_8O_7$, is found in oranges, lemons, and gooseberries; *Malic acid*, $C_4H_6O_5$, is met with in fruits belonging to the rose order, such as apples and pears; *Oxalic acid*, $C_2H_2O_4$, is present largely in rhubarb and sorrel; *Acetic acid*, $C_2H_4O_2$, constitutes the active element in vinegar. Except it be the latter, all these vegetable acids contain more than sufficient oxygen to convert all their hydrogen into water. These acids exist mainly in

fresh fruits and vegetables, either as free acids or in combination with alkalies as alkaline salts, and, when taken into the body, form carbonates, which exercise a controlling influence in preserving the alkalinity not only of the blood but other fluids; they also furnish a small amount of energy and heat by oxidation. Their absence for any length of time from any dietary leads to a disturbance of nutrition. It is possible that some of these acids are not only derived from fruits and vegetables, but also in a small degree from the splitting up of carbohydrates, so that even the latter, in an indirect way, help in maintaining the alkalinity of the blood and other animal fluids.

Vitamines.—These are certain accessory principles present in all fresh food stuff or in food which has not become degraded or dried excessively, or exposed to high temperatures. Their chemical composition is unknown, but it is probable that they have a nitrogen basis. Their function appears to be to act as activators or stimulators for the essential physiological changes in the body following the ingestion of food and its proper conversion into the various tissues and liquids which go to the make-up and maintenance in health of our body. Fresh milk is particularly rich in vitamines, and so are most of the vegetable foods such as rice and potatoes, and also most of the fruits. The vitamines appear to be concerned intimately in nutrition, and for this reason may be called accessory growth substances. Their absence from dietaries is associated with the production of what have been termed deficiency diseases, such as rickets in children, scurvy, beri-beri, polyneuritis and a certain sloughing and ulceration of the cornea of the eye in advanced conditions of starvation or mal-nutrition. Three groups of vitamines are recognized. One is a fat soluble substance and present in all fresh animal fats, but absent from most vegetable oils. This vitamine is not readily affected by heat, but sensitive to oxidation, is present largely in fresh normal milk, and appears to play a large part in the prevention of rickets. The other two varieties of vitamines are both soluble in water. One of them exists largely in the inner coat of rice and is the anti-neuritic factor which plays so large a part in the prevention of beri-beri and the polyneuritis of the tropics. It stands desiccation, but is susceptible to a temperature of 70° C. The other water-soluble vitamine is the anti-scorbutic factor. It is present in milk and in the juice of many fruits, especially in limes from Sicily and the Mediterranean, less so in other varieties, in oranges and other fruits. The vitamine is tolerant of drying slowly and of a temperature to 70° C. In the past, much of the action which we now recognize as due to the presence of vitamines was attributed wrongly to the vegetable

acids and fruit juices. Quantity of vitamines is as essential as quality, but at present we cannot dogmatize as to dosage.

The Nutritive Value of the Food Stuffs.—In the preceding pages we have learnt the part which the various food stuffs play when taken into the body; it is now necessary to learn their nutritive value. To begin with, if we lift a weight by our hands, muscular force is employed in the act, and the energy evolved in this or any other muscular action must have its origin or source in something. As a matter of fact, the energy so evolved has its source in the material which has been supplied to the body in the form of food. Every process of our bodies, no matter whether it be the moving of a hand or a foot, the beating of our heart, or the secretion of saliva, is attended with some manifestation of energy, and this energy is shown in one or other of two forms, namely, either mechanical labour or heat. Just as coal is burnt on the fire so food is burnt in our bodies. True, it is burnt more slowly and with the production of no severe heat, but the process is the same with the same result, warmth. Further, the food produces power for all our actions, and the amount of power at our command depends upon the energy or fuel value which our food gives. The problem, however, is not of a very simple nature. In the case of the water and mineral salts of the food, their nutritive value is not difficult to ascertain, because they are simple bodies, and do not undergo any very great chemical change in the body. The nutritive value of the proteins, fats, and carbohydrates, however, is not so easy to determine, because not only are they complex bodies in themselves, but, moreover, undergo complicated and ill-understood changes within the body; their nutritive value, therefore, cannot be very accurately expressed.

The various statements as to the potential energy possessed by food stuffs are synonymous with and proportional to the heat yielded by definite quantities during their combustion under definite conditions. The standard measure of heat is the Calorie. This heat or food unit is the amount of energy required to raise the temperature of 1 kilog. (or 1 litre) of water 1° C., or, which is the same thing, 1 lb. of water 4° F. This heat unit corresponds to 425,500 units of work, which are grammetres; or a weight of 425·5 kilogs., if allowed to fall from a height of 1 metre, would by its concussion produce as much heat as would raise the temperature of 1 litre of water 1° C. In other words, one Calorie, as a measure of the work derivable from a food stuff, is equal to 425·5 kilogrammetres.

According to the English system the heat unit is the amount of energy required to raise the temperature of a pound of water

1° F., and will, if manifested as a mechanical force, raise 772 lbs. a foot high, or, what amounts to the same thing, 1 lb. 772 feet high. Thus the dynamic or mechanical equivalent of one degree of heat on the Fahrenheit scale is said to be 772 foot-pounds. Adopting the Centigrade scale, then the mechanical equivalent of 1° C., or 1°·8 F., will be 1389 foot-pounds; that is, the energy which will raise the temperature of 1 lb. of water 1° C., or 1°·8 F., will be capable, as a motive power, of raising 1 lb. in weight 1389 feet high. In England the amount of work done is commonly expressed as foot-tons or tons lifted 1 foot; while in France it is often expressed as kilogrammetres or kilogrammes lifted 1 metre.

Units of work, expressed according to the continental system as gramme-metres, can be converted into foot-pounds by multiplying them by 0·007233, and into foot-tons by dividing by 311,000. Similarly, kilogrammetres are converted into foot-pounds by multiplying by 7·233, and into foot-tons by dividing by 311; also Calories into foot-tons by multiplying by 1·36.

Applying this principle, that as heat production is related to the amount of chemical action ensuing, so likewise is mechanical power production, we find that as a measure of the utility of food, the value of the various food principles as mechanical power producers will correspond with their value as heat producers. Those food principles, which by oxidation give rise to the greatest amount of heat, will, of course, theoretically have the greatest capacity for the production of working power; that is, will possess the greatest potential energy. This theoretical potential energy is not only different in the case of each class of food stuff, such as protein, fat, and carbohydrate, but differs also in different foods of each of these classes. In the case of many food stuffs, their actual value in respect of capacity for heat production has been determined experimentally, and expressed in relation to the performance of work.

The following table gives the number of Calories yielded by the complete combustion of 1 pound of some common articles of food:—

Dripping	4185	Cheese	1777
Lard	4006	Oatmeal	1732
Butter	3600	Ham	1670
Margarine	3560	Macaroni	1660
Suet	3425	Flour (wheat)	1650
Chocolate	2853	Cornflour	1648
Bacon, 16 % bone	2275	Tapioca	1642
Sausage	2130	Arrowroot	1642
Pork	1870	Rice	1631
Sugar	1822	Beans, peas, lentils	1626
Biscuit (unsweetened)	1800	Fat beef, no bone	1620

Maize meal	1609	Jam or marmalade . .	945
Currants and raisins . .	1536	Salmon	730
Honey	1520	Eggs	624
Figs	1470	Liver	580
Dates	1420	Rabbit	556
Mutton, no bone . . .	1306	Herrings	438
Tinned beef	1280	Potatoes	395
Beef, average, no bone .	1218	Milk, 1 pint	315
Bread	1200	Tripe	270
Cream	1093	Cod	228
Beef, 18 % bone . . .	1000	Carrots	158
Mutton, 20 % bone . .	993	Turnips	127
Sardines	952	Cabbage	124

The above figures refer, of course, to laboratory experiments, involving a complete combustion of the food stuff, but in the body it is practically only the fats and carbohydrates which are completely burnt; while the proteins are not metabolized beyond the stage of urea, which we know escapes in the urine. Rubner has shown that, if allowance is made for such incompletely oxidized products, the heat value of 1 grm. of the chief alimentary principles, when taken into the body, is as follows:—

	Calories.
Protein	4·1
Fat	9·3
Carbohydrates	4·1

If we know what is the percentage composition of any given food in terms of protein, fat, and carbohydrates, it is quite easy to find the total Calories yielded by 100 parts of the food in question. The Calorie value of statements made in ounces is readily obtained by multiplying by 28·34, or, in other words, an ounce of protein or carbohydrate yields 116 Calories and an ounce of fat yields 263·5 Calories.

The following table shows the percentage composition of the more ordinary articles of food in terms of protein, fat, carbohydrates, salts, and water:—

	In 100 parts—				
	Water.	Proteins.	Fats.	Carbo-hydrates.	Salts.
Arrowroot	15·40	0·80	—	83·5	0·30
Bacon (Letheby)	15·00	9·00	73·00	—	3·00
Barley meal (de Chaumont)	11·30	12·70	2·00	71·00	3·00
Barley pearl (Church)	14·70	7·40	1·10	75·80	1·00
Beef, best quality (Konig)	72·00	21·00	6·00	—	1·00
Beef as supplied to army	75·00	15·00	8·40	—	1·60
Beef, salted	49·10	29·60	0·20	—	21·10
Beef, corned or Chicago (Parkes)	52·20	23·30	14·00	—	4·00
Beetroot (König)	87·00	1·50	—	10·50	1·00
Biscuits	8·00	15·60	1·30	73·40	1·70
Bread (Rubner)	39·50	8·00	1·00	50·00	1·50
Bread, average wheaten	40·00	8·00	1·50	49·20	1·30
Butter, English fresh (Bell)	12·00	2·00	85·00	—	1·00
Butter, very best (Bell)	8·00	1·00	90·00	—	1·00
Butter, salt (Bell)	17·00	—	80·00	—	3·00
Butter, highly salted (Bell)	17·00	1·00	74·00	—	8·00
Cabbage (König)	89·00	2·00	2·00	5·50	1·50
Cabbage, Brussels sprouts	85·50	5·00	0·50	7·80	1·20
Carrots (König)	87·80	1·00	0·20	10·00	1·00
Cheese, Dutch (Bell)	41·00	28·00	23·00	1·00	7·00
Cheese, Single Gloster	36·00	31·00	28·50	—	4·50
Cheese, poor quality (Bell)	48·00	32·00	9·00	7·00	4·00
Cream (Letheby)	66·00	2·70	26·70	2·80	1·80
Eel (König)	57·50	12·50	28·50	—	1·50
Eggs	73·50	13·50	11·60	—	1·40
Fish, salmon (König)	76·00	15·00	7·00	—	2·00
Fish, sole (Konig)	86·00	12·00	0·50	—	1·50
Fish, herrings fresh (König)	80·00	10·00	8·00	—	2·00
Flour, wheaten fine	16·50	13·00	1·50	68·30	0·70
Flour, wheaten average	15·00	11·00	2·00	71·20	0·80
Goose (König)	38·00	16·00	45·50	—	0·50
Horse-flesh (König)	74·30	21·70	2·60	—	1·00
Lentils	12·50	24·80	1·80	58·40	2·50
Macaroni (König)	13·10	9·00	0·30	76·80	0·80
Maize (Pozziali)	13·50	10·00	6·70	64·50	1·40
Margarine	12·03	0·75	82·00	—	5·22
Milk, average cows	86·90	4·70	3·50	4·20	0·70
Milk, Devon preserved (Blyth)	90·35	4·20	1·15	3·50	0·70
Milk, average town	86·00	5·00	4·00	4·30	0·70
Milk, condensed English (Bell)	27·00	12·00	8·40	50·80	2·00
Milk, condensed Swiss, sweetened	25·60	12·30	11·00	48·70	2·40
Milk, condensed Swiss, unsweetened	61·85	11·35	11·25	13·35	2·00
Mutton, ordinary	76·00	18·00	5·00	—	1·00
Oatmeal	15·00	13·00	6·00	63·00	3·00
Parsnips (Parkes)	82·50	1·30	0·70	14·50	1·00
Peas	15·60	22·00	2·00	58·00	2·40
Pork (König)	47·50	16·00	34·00	—	2·50
Potatoes	74·00	2·00	0·20	21·84	1·00
Rice	10·00	5·00	0·10	84·40	0·50
Turnips (König)	91·00	1·00	0·20	6·80	1·00
Veal, lean (König)	78·00	19·00	1·50	—	1·50

With a table of this kind, it is quite easy to calculate the amount of protein, fat, carbohydrates, water, and salts in any given weight of a food stuff and from these data its Calorie value. However, the mere expression of potential energy cannot fix dietetic value; in order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. For these reasons it is difficult to compare rightly the potential energy available by the burning of a food stuff outside the body with that which is obtained as the result of combustion within the body, and in attempting to estimate the nutritive values therefrom, allowance must be made for the different degrees of digestibility, the effects of cooking, or preservation with consequent destruction of vitamines, and even the actual bulk taken. In the case of fats, their nutritive value seems to depend largely on their digestibility, while of the carbohydrates there is little reason to think that starch, grape sugar, or cane sugar differ much in their nuitritive value, though experiments indicate that cane sugar is more fattening than starch. Among the proteins, we know that gelatin and chondrin have a lower nutritive value than the ordinary proteins, and that vegetable proteins are as nourishing as the animal.

With regard to mechanical or useful labour and the amount of energy required to be supplied by food to produce that external work it is estimated that, under ordinary circumstances, a man transforms one-sixth of the total available energy of his food into work, the rest being lost in the form of heat. This loss is inevitable, but it compares favourably with that experienced in a steam engine, where the work done is about one-eighth of the potential energy of the fuel consumed. As the average external work of an ordinary man at rest is calculated to be equivalent to some 410 Calories, the total heat value of his food should not be less than six times this or say 2500 Calories. On this basis the following may be accepted as standards of the number of Calories which must be supplied for work of different degrees of severity:—

	Calories.
1. Rest (clerk working in an office)	2500
2. Professional work (lawyer or doctor)	2650
3. Moderate muscular work	3100
4. Severe muscular work	3600
5. Hard work (navvy)	5000

Diets.—So far, we have discussed the nature, uses, and nutritive values of the food stuffs individually; it is necessary now to briefly discuss them collectively in reference to their powers of maintaining life—whether any one of them alone is capable

of supporting vitality, or what combinations and what quantity of them experience and experiment teach us are useful in the food of man. There is abundant evidence to prove that no one group of alimentary substances is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from instinctive proclivities, from considerations of the comparative anatomy of our digestive organs, from experience and experiment. That man cannot live on any one group of the food stuffs is shown by an examination of the needs of the body, as demonstrated by the daily loss by the kidneys, bowels, skin, and lungs.

Experience teaches us that our requirements as to food vary much with our exposure to different conditions, and that according to the expenditure of our bodies so should the materials be supplied which are best calculated to yield what is wanted. The human body has been compared to a machine, but it differs therefrom in this, that wear is constantly going on independently of any useful work done, which is not the case in a mechanical engine. Determinations as to the quantity of food daily required by the body have been obtained by means of extended observations of the diets of classes and communities, and also by estimating the sum of excreted matters, which, of course, must be compensated by a suitable supply of food.

The following table (modified from Atwater) gives the composition of the ordinary diet actually consumed by individuals of diverse nationality and different social rank :—

Classes.	Nutritive constituents.				Potential energy.
	Protein.	Fat.	Carbo-hydrate.	Total.	
	Grammes.	Grammes.	Grammes.	Grammes.	Calories.
Sewing girl (London) . .	53	33	316	402	1820
Factory girl (Leipzig) . .	52	53	301	406	1940
Labourer (Lombardy) . .	82	40	362	484	2192
Student (Japan)	97	16	438	551	2343
Lawyer (Munich) . . .	131	95	327	553	2700
Master tailor (England) .	131	39	525	695	3053
Blacksmith (England) . .	176	71	667	914	4117
Workman (Russian) . . .	132	80	583	795	3675
Glass-blower (American) .	95	132	481	708	3590
Artisan (Canada) . . .	109	109	527	749	3622
Brickmaker (American) .	222	260	758	1243	6460
Weaver (Lancashire) . .	114	150	522	786	4000

Interesting as these figures are, care needs to be taken that

their limited range of usefulness is not forgotten. They indicate the needs of typical individuals living under known conditions, but they cannot be applied rigidly in any or every particular case. The facts show strikingly the relation between the muscular activity of the individual and the caloric value of his diet and, on that account, are exactly what is to be expected from the theory of the conservation of energy. The most obvious lesson to be learnt from these actual dietaries appears to be that (1) people doing active muscular work, such as blacksmiths and athletes, when free to choose their diet, select a dietary having a total fuel value of some 4400 Calories; (2) people doing ordinary muscular work, such as carpenters, farmers and labourers, choose a diet representing some 3300 Calories; (3) people doing light muscular work, such as professional men and clerks, select a dietary representing about 2500 Calories.

We may now inquire what light physiological experiment throws on this subject, more particularly what proportion of the whole diet, protein, fat and carbo-hydrate, should each contribute. The metabolic output of an individual varies naturally with his size, age and work, but it may be said that an ordinary man, weighing 70 kilos or 11 stones, excretes 20 grammes of nitrogen and 300 grammes of carbon daily.

Assuming protein to contain 16 per cent. of nitrogen, it is clear that an input of 125 grammes of protein will supply the requisite amount of nitrogen, but we cannot accept this as the absolute answer to the question as to how much protein such a man must consume daily, owing to the fact that the body can establish nitrogen equilibrium on various quantities of protein. In a typical man, 20 grammes input of nitrogen means 20 grammes output, so also 15 grammes input is followed by 15 grammes output, and so on, the nitrogen excretion keeping pace with the nitrogen intake. The question arises, how much is the best? The answer is not easy, because we do not know how much protein or nitrogen is actually needed to keep the tissues in repair. A starving man will eliminate 4 grammes of nitrogen daily, and, practically, nitrogenous equilibrium cannot be established on less than an intake of 12 grammes. Can we accept this as the minimum? The view held, hitherto, by physiologists is that we cannot, because, when the protein is reduced to a minimum, there is a risk of having "threadbare tissues" and a consequent lack of disease-resisting power on the part of the body; moreover, to do so is to ignore the fact that the function of protein is to supply energy as well as merely repair tissues, and that it is unsafe to rely only on the fats and carbohydrates as sources of heat and energy. On this principle it has been held

that the proper nitrogen standard for the ordinary man of 70 kilos weight is 118 grammes of protein daily. This represents 105 grammes of absorbable protein or 16 grammes of nitrogen and equivalent to 1·5 grammes of protein per kilogramme of body weight.

Recent work on metabolism has seriously challenged this view. On the one hand, theoretical reasoning from the fact that an excess of nitrogen is so rapidly eliminated from the body and, on the other, practical experiment suggest that protein in this large amount is not necessary in health to supply the needs of the body, but rather increases the work of nitrogenous excretion with no apparent advantage. Chittenden, as the result of a long series of experimental observations, has been the main exponent of this view. He argues that 0·1 gramme of protein capable of metabolism per kilogramme of body weight represents the minimum protein requirement daily, but, as it would probably be advisable to allow a margin of safety, he suggests that a daily input of from 50 to 60 grammes of protein is sufficient for a man of from 60 to 70 kilogrammes weight. This is virtually a reduction of fifty per cent. on the generally accepted standard.

It may be asked what practical conclusion is to be drawn from these divergent views? It is probable that the orthodox standard of 118 to 125 grammes of protein daily may err on the side of excess for the ordinary man doing no specially hard work; equally, the newer idea of reducing the amount to half may be open to risk if accepted as a standard for the general population. From the available evidence, we do not think it has been proved that a diet containing protein in a much smaller proportion than that of 100 grammes a day for an adult of 70 kilogrammes, is permanently beneficial either to the individual or to the race, and especially for those whose occupations require considerable muscular exertion.

We may now pass on to inquire how much fat and carbo-hydrate are required in a daily diet. These two alimentary groups are the main source of the carbon supplied to and needed by the body and also of the energy. For a man of 70 kilogrammes in body weight, doing ordinary work, some 300 grammes of carbon are needed daily to meet the daily loss under this head. If we assume that a man takes in 100 grammes of protein of which only two-thirds is fully metabolized, we get 36 grammes of carbon available from this source, leaving 264 grammes to be supplied by fats or carbo-hydrate. So far as a mere source of energy is concerned, the body cells are indifferent whether it be fat or carbo-hydrate, but we must remember that it takes $2\frac{1}{4}$ parts of the latter to supply as many Calories as one of

the former. On the other hand, fat is more slowly metabolized than carbo-hydrate, is more expensive, and usually less digestible. Experience indicates that for economic and digestive reasons, about one-fifth of the balance of carbon should come from fat, in other words, some 60 grammes of fat are desirable, yielding 46 grammes of carbon, the remaining 218 grammes of carbon being obtained from an input of 540 grammes of carbo-hydrate. A dietary prepared on these lines would have a fuel value of 3182 calories; possibly the fat might need to be reduced, say, to 50 grammes, in which case, unless it were replaced by carbo-hydrate, the fuel value of the dietary would not be more than 3089 Calories. What should be the exact proportion of fat to carbo-hydrate is difficult to say; in our opinion, the ratio in a well-designed dietary should be 1 part of fat to 7 or 8 of carbo-hydrate, but it is impossible to lay down any hard and fast rule: opportunity, digestion and pecuniary circumstances are the determining factors.

The general principles of diet may be summed up thus: (1) No single nutritive principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a long time, but for a permanency salts would require to be added. Thus proteins and fats, or proteins and starches, would support life. (3) For the best forms of diet, both fats and carbo-hydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar among them. It would also appear that a due admixture of more than one form of nitrogenous principle is advisable.

Various conditions of life influence the amount of food required; the more important of these are work, rest, weight, age, sex, and climate. No one disputes the view that with an increase of *muscular work* there must be a corresponding increase in the total amount of food consumed; the problem is, should it be met by an increase of protein, of fat, or of carbo-hydrate or should all be increased? As modern research indicates that muscular work makes no special demand on one nutritive constituent more than another, it is logical to assume that all must be increased. The standard amounts of the different nutritive constituents required daily, when doing ordinary and hard work, may be stated thus:—

Kind of work.	Protein.	Fat.	Carbo-hydrate.	Potential energy.
	Grammes.	Grammes.	Grammes.	Calories.
Ordinary work . . .	100	60	540	3182
Hard work	161	98	520	3706

These amounts are, of course, theoretical standards, and, as such, only approximate. The need of so great an increase in the proteins during hard work is doubtful, while, on the other hand, the need of carbon under the same conditions is possibly greater than given in the above table. As already stated, all the ingredients are reckoned as being quite free from water, but would in actual practice be combined with quite their own weight of water, making the total weight of solid food taken to be from 40 to 20 ounces. In addition, too, some 40 to 60 fluid ounces of water would be taken as drink. As a general rule, it may be accepted that a man consumes daily about $\frac{1}{100}$ of his own weight of dry food, and some $\frac{3}{100}$ of water, or, in other words, each pound of his body weight receives in twenty-four hours 0·15 oz. dry food and 0·5 oz. of water.

It will be readily understood that, though the above-named amounts are accepted as standards, in actual life there are very great individual differences in diets, and that no single standard will meet all cases, because no two men eat exactly the same. The chief influences which affect the amount of food and drink taken are sex, age, work, and climate.

As regards *sex*, women are said to require 10 per cent. less than men; while in reference to *age*, during young life nitrogenous and fatty food are particularly needful to provide for the growth of tissues; in old age, proportionate reductions are demanded, as there is not only lessened labour but actually lessened body metabolism or tissue change. If people are doing great *work*, there is a natural need of more food, especially for proteins and fats; also in a less degree for water. The influence of *climate* on diet is not very defined. In cold countries more fat is consumed than in hot, but how far this increase is due to greater need for energy and body warmth or increased exertion is not quite clear.

It is the great diversity which exists as regards the food consumed by the human race in all parts of the world that is the most remarkable feature in the study of dietaries. Some people live upon a wholly vegetable, others on a wholly animal, and others on a mixed diet. It has already been explained how unsuited any single vegetable food, such as bread, or any single

animal food, such as meat, is to supply the daily requirements of the body, and how a judicious mingling of the various food stuffs affords the greatest nourishment in the least bulk. The mixed diet may be regarded as that which in Nature's plan is designed for man's sustenance. On this he appears to attain the highest intellectual and physical vigour, and it is this diet which he consumes by general inclination when circumstances allow the inclination to guide him; also it is in conformity with the construction of his teeth and the arrangements of his digestive apparatus in general. However, where custom and habit have given certain races a peculiar suitability for a purely vegetable diet, the arguments in favour of a mixed diet are not sufficiently strong for the reversal of the customs of many ages.

For translating or changing the elements of a diet into terms of food articles, or *vice versâ*, it is important to remember that no mere calculation of the amounts of food stuffs can properly measure the efficiency of any particular diet, but that other conditions must be considered; the chief of these will be relative to hours and arrangements of meals, digestibility of food, and the effects of cooking.

Hours of Eating.—Next to the quantity and quality of food, attention must be given to the method of taking it. Food should be taken with regularity and at proper periods; long intervals between meals are specially hurtful. As a rule, it may be said that the hours of eating meals are the result of custom and of the other trivial conditions peculiar to different classes of society. The prevailing custom is for these meals to be taken during the day at intervals of about five or six hours. Observation has shown that an ordinary meal is digested and has passed on from the stomach in about four hours' time, and thus, according to the above custom, the stomach is allowed to remain for a short period in a state of rest before it is filled with food again. Whether the largest meal of the day, dinner, should be taken at midday or at sundown is a question mainly to be decided by circumstances. The former hour is found to be more convenient to men doing manual labour, while the latter seems to be best adapted to the wants of the busy man in the upper and middle classes. Provided the evening meal is not taken at too late an hour, and not too large, there is no reason against this arrangement; but it must not be forgotten that the habit of going to bed or to sleep on a full stomach after a meal is particularly injurious. Similarly, a hearty meal should neither follow nor precede violent exertion. In each case, the stomach is unfit for the vigorous discharge of its office. All persons, both rich and poor, should endeavour to take a little food with either a cup of hot tea or coffee in the

early morning before going out to work. Such a practice strengthens the body and digestion at a time when its powers are at their lowest, and, too, in malarial countries has a marked influence in keeping off fever.

Digestibility of Food.—Far more important, as an index of its nutritive value, than mere calculations as to how much protein, fat, etc., a given article of food contains, is the determination of the degree of its digestibility. On this point it may be said that the proteins and fat derived from the animal world are more readily digested than those obtained from vegetables. As to the carbohydrates, no general rule can be laid down beyond that white bread and rice are the most digestible. These statements must, however, be regarded only as giving broad differences of digestibility between foods, and in particular cases may be considerably modified, especially if allowance be made for the effects of cooking.

Cooking.—By cooking, our food is rendered more pleasing to the eye, agreeable to the palate, and digestible by the stomach. Apart from its power of removing any obnoxious property in a food by killing any parasites or disease germs existing in it, cooking so alters the texture of a food as to render it more easy of mastication and subsequent reduction to a fluid state by the stomach. Thus a piece of meat before cooking is tough and stringy, but when cooked the muscular fibres are given a firmness from the coagulation of their albumin, and the connective tissue which binds the muscle-fibres together is made into a soft and jelly-like mass. The result of all this is, the meat is rendered less coherent and more digestible, and capable of being broken down by the teeth and the digestive juices. In the same way, cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices to penetrate into their substance. It also aids digestion by its action of breaking up the starch granules, which exist so largely in vegetables and grains; if not so broken up, starch offers considerable resistance to digestive action. The warmth imparted to food further aids digestion, and exerts a reviving effect on the system.

We may say that there are six common methods of cooking; namely, boiling, stewing, roasting, broiling or grilling, baking, and frying.

Boiling.—This may have for its object either the extraction from the food of its nutritive principles or their retention in it. If we wish to extract all the goodness of meat into some surrounding liquid such as water, as when we make a soup or a broth, the article should be finely cut up and placed in cold water. After it

has soaked for some while, heat should be applied slowly; if a broth is to be made, the heat, though constantly applied, is not allowed to reach actual boiling for some time, by which procedure much of the albumin of the meat is extracted before the subsequent greater heat has been able to coagulate it, and, all the natural juices having for the most part flowed out, the meat itself is left in a nearly tasteless state, but not without some nutritive value. In the making of a soup the same procedure is adopted, with this difference, however, that the boiling is kept up somewhat longer, whereby more of the gelatin of the meat is extracted, and the actual meat itself, owing to more complete deprivation of its constituent juices, rendered still more tasteless and less nutritious. Thus treated, the meat yields its essential principles to the surrounding liquid, which gains in flavour and nutritive properties, the essential difference between the broth and the soup being merely one of degree—that is, how much of the goodness of the meat passes out of it into the surrounding liquid. In the making of a broth some of the meat juices, gelatin, and other constituents still remain in the meat, because the albumin is permitted to coagulate before they have all escaped; while in the other case practically nothing remains of the meat but fibrous tissue, all the rest having passed out into the soup. A due appreciation of the difference between a broth and a soup is important, especially the fact that after the making of a broth the meat residue has still considerable nutritive value, whereas after the preparation of a soup the meat residue has none.

If, on the other hand, the object of boiling is not to extract the constituents out of meat, but rather to retain in it all its flavour and nutriment, then it should not be cut up, but left as a large piece, plunged suddenly into hot or nearly boiling water, and quickly brought to the boil. The application of sudden heat in this manner coagulates the albuminous matter on the surface of the meat, closes its pores, makes an impermeable external coat which stops the escape of the juices from the inner and deeper parts. It is on this principle that a boiled leg of mutton is cooked, taking care, in order to complete the cooking, that the boiling is neither too vigorous nor too long continued, but, after the first short period of boil, the water is only just allowed to simmer—that is, be barely at the actual boil. If cooked carefully in this way, the central part of such a joint remains juicy and tender. The most usual fault of cooking meat in this manner is allowing the water in which it is boiled to remain at too high a temperature after the first dipping in to coagulate the surface. The actual period of boiling need not and should not last longer than a few minutes; after that the temperature required for the

surrounding water is not greater than 160° F., actual boiling being 212°. It is usual to add salt to the water in boiling a joint such as has been just explained. There are certain reasons for so doing: first, it has a direct coagulating effect upon the surface albumin; second, it slightly raises the boiling-point of water; and third, it increases the density of the water, the effect of which is to render less active the oozing out of the meat juices.

The same principles should guide us in boiling a fish, but with this reservation—namely, that fish being relatively fragile as compared with red meat, many kinds would break if suddenly dipped into boiling water. To avoid this, water just below the boiling-point must be used, and the whole process of cooking the fish be completed without actually boiling the water at all. The breaking of a fish by the agitation of boiling water not only spoils the look of the fish, but also opens up the flesh, producing outlets for the escape of its juices, and thereby losing some of its nutritive elements, besides spoiling its flavour. One of the most prevalent errors amongst unscientific cooks is the idea that by boiling is meant vigorous bubbling of the water: more good is done, and just as much heat obtained, by a very gentle simmer of the water as there is when the saucepan lid is constantly being lifted. The cooking-point of meat is a temperature of 160° F., while the boiling-point of water is 212° F. The same principle of trying to retain the soluble and diffusible constituents of a food is involved when potatoes are boiled in their skins; but in the case of a vegetable like the potato, we retain its constituents within it, not by coagulating any surface albumin, because there is none, but by boiling them in their skins or jackets. Over 50 per cent. of the saline constituents of the potato is potash, and potash is an important constituent of blood, hence the great importance of not allowing any waste of the potash from the potato by allowing it to be largely dissolved out of it during the act of cooking by boiling after peeling. It will readily be seen that this loss of potatoes does not occur when potatoes are cooked in such a manner as to be eaten with their own juice (broth) as in Irish stew, in which case their previous peeling does no harm. Steamed potatoes possibly lose less potash juice than when boiled. Speaking generally, boiled food is less tasty, but more digestible than when cooked in any other way.

It will be convenient here to discuss another cooking method, namely, *stewing*, because it is commonly regarded as a mere modification of boiling; this is only partially true, because they are essentially opposite processes. If the reader has understood what has been written above upon the boiling of a leg of mutton, he will see that its object is to so raise the temperature of the

meat, using water as the medium by which the heat is conveyed to the meat, that it shall as nearly as possible retain all its juices. Now, in stewing, this is largely reversed, because the water is used not only as a heat-giver, but also as a solvent for extracting from the meat more or less of its juices. Much of this extraction of meat juice in stewing is more accurately expressed as an act of diffusion rather than of solution, capable of being best secured at high temperatures than low; but experiment teaches us that albumin, which so largely constitutes the diffusible juice of meat, coagulates and gets hard and tough if long exposed to a heat anything near the boiling-point of water; hence the need, if stewing is to be properly done, and the meat not rendered so tough, curled, and hard as to be more or less uneatable, that the process of stewing should be performed at a temperature of 160° F. or so. This can be readily done if a *bain-marie*, or water bath, be used. The ordinary carpenter's glue-pot is a familiar form of water bath, being simply a vessel immersed in an outer vessel of water. The water in the outer vessel may boil, but that in the inner one never does, because evaporation from its surface keeps its temperature lower than that of the water from which it gets its heat. All well-equipped kitchens have these double vessels, and every ironmonger sells them; but in the absence of such a double saucepan, every housewife can readily improvise one by performing the stewing in an earthenware jar or glass placed within an ordinary saucepan containing water. It is the more general appreciation of the value and use of the water-bath mode of stewing by French men and women that makes their average cooking so much higher than that of the average English man or woman. English people are apt to speak with contempt of the stewed beef of the Frenchman, forgetting the fact that he never eats it alone, but always associated with a soup or *potage*, which really contains the juices of the beef; and the two dishes combined constitute identical and quite as nutritious articles of diet as the British joint.

Hashing is the same process as stewing, only that the meat has been previously cooked instead of being fresh.

Before dismissing this subject of stewing, a few remarks upon the making of ordinary beef-tea or beef extracts as sold under the names of "extract of meat" and "Bovril" may not be inappropriate, particularly as they afford some points of difference from the juices of an ordinary stew. Beef-tea is made by chopping up lean meat very finely and then macerating it in cold water, and the broth thus obtained heated in order to alter its raw flavour. During this heating, which should not exceed 160° F., or just sufficient to coagulate the albumin and colouring matter, a sort of scum rises to the surface; much of this is fat, and is rightly

removed, but if the heating is carried too high, some of the other nutritious elements coagulate on the surface, and get removed instead of being left behind. If well prepared, beef-tea is a highly nutritive and restorative liquid, with an agreeable, rich, meaty flavour. If badly prepared, by being subjected to prolonged boiling, beef-tea is merely a solution of the non-coagulable saline constituents of meat—namely, bodies known as kreatin, kreatinin, lactic acid, and phosphates. These are all most excellent, but to be regarded as stimulants rather than as nutrients. This explains why in some states of prostration, during illness, when the blood is insufficiently supplied with these flesh juices, the administration of beef-tea, beef extracts, and such-like preparations does much good; but the danger lies in their being regarded as foods suitable for the normal sustenance of the body. This they are not, and, from the very nature of their composition, wanting largely of the nutritious constituents of meat, they never can be.

Roasting.—Just as stewing may be regarded as the national method of cooking on the Continent, so may roasting be regarded as our national method of flesh cooking. Roast meat is usually thought to be more savoury but less digestible than when either boiled or stewed, while, too, the loss is greater, but the same principle underlies it, namely, the retention of the nutritive juices by the formation of a coagulated layer on the surface. In roasting the juices of the meat are retained (with the exception of those which escape as gravy on the dish), while in stewing, they go more or less completely into the water. In stewing, the heat is communicated to the meat by convection or actual contact; in roasting, the heat is nearly all dry heat radiated to the surface of the joint from the fire. The high temperature rapidly given by radiation to the meat surface forms a thin crust of hardened and half-carbonized albumin; this prevents the evaporation of the meat moisture, sets up a certain amount of pressure inside the joint resulting in the gradual loosening of the fibres and raising of the deeper parts of the flesh to the cooking temperature of about 160° F. In all roasting processes, to hasten its course and prevent burning of the superficial parts, the joint is *basted* or kept constantly enveloped in a varnish of hot melted fat, which, while assisting in the communication of heat, checks the undue evaporation of the juices, or, in other words, during roasting heat convection is established by the medium of a fat bath, while in stewing or boiling it is supplied by a water bath. This mode of cooking in a fat bath is applicable not only to ordinary joints but to fish, which, in the form of fillets of plaice or skate, supplemented by roasting in bacon fat and garnished with some

previously well-boiled haricots, constitute both a savoury, cheap, and nutritious meal for any poor man.

Broiling or *grilling* is the same in principle as roasting, but the scorching of the surface is greater owing to the larger surface exposed to heat. Baking is analogous, except that the operation is carried on in a confined space, such as an oven. Owing to the confined space and want of ventilation in the chamber or oven in which baking is carried on, the condensed vapour from the article being cooked and the fatty acids, if it be meat, are prevented from escaping, rendering the food so cooked richer and stronger for the stomach. For these reasons, baked food is unsuitable for the sick and delicate.

Frying, speaking generally, is a bad way of cooking, as owing to the heat being applied through the medium of fat, the article so cooked is penetrated with oily matter and often indigestible. In frying, the heat is applied usually much above that of boiling water, as the medium fat can be heated much above 212° F. before it boils; and it is probably largely the difference of temperature to which fish is subjected in the two processes that causes the difference between a boiled sole or mackerel and a fried one Over and above this, their difference may be due to the fact that the flavouring juices are retained in the flesh of the fried fish, while more or less of them escape into the water when boiled.

It is needless, perhaps, to say that all things used in cooking should be scrupulously clean and carefully cleansed with boiling water after each time of use.

Diseases attributable to Faulty Dieting.—That evils may arise from the indigestibility and bad cooking of food has already been alluded to. There remain for consideration certain bad effects which may arise from either defects as to quantity or quality. The alterations in quantity of food may be either in the direction of excess or deficiency. *An excess of food*, due to too large or too frequent meals, usually leads to an accumulation in the bowels resulting in dyspepsia, constipation, or even irritative diarrhœa. The excess of food may in some cases be absorbed, but more usually large quantities pass away by the bowel absolutely undigested. Any excessive consumption of proteins, especially if unaccompanied by a proportionate increase of exercise, usually results in enlargement of the liver with more or less dyspepsia, diarrhœa, or even gout, the urine containing an excess of urea, uric acid, and even albumin. An excessive consumption of proteins, with a proportionate reduction of fats and carbohydrates, was the basis of so-called "Banting;" it being an attempt to reduce accumulation of fat in the body by virtue of the well-recognized power which proteins have of favouring a rapid dis-

integration of tissue. Though physiologically sound, banting is unsuited for indiscriminate use as a means to reduce corpulency. An excess of fats or carbohydrates tends to produce stoutness more or less associated with acidity and flatulency, and if continued long, to degenerative changes in the muscles. Little is known of the effects of any excess of mineral salts. Common salt taken in excess increases the change of protein in the body; while an excess of potash salts in the food leads to an increased excretion of sodium chloride. An excess of water with the food means more urine passed, and also increased tissue activity.

Deficiency of food, if protracted, means, of course, a wasting of the tissues as shown by loss of flesh, poorness of blood, followed by physical and mental weakness, and if the loss reach 40 per cent. of the normal weight of the body—death. The more or less complete deprivation of proteins gradually leads to loss of muscular strength, mental debility, fever, and eventually a degree of prostration which may end in loss of life. A deficiency of fats, even if carbohydrates be given, invariably leads to a lowered state of health. A deficiency or even complete withdrawal of carbohydrates can be borne a long time if fats be given, but a deprivation or deficiency of both fats and carbohydrates although proteins are supplied, soon leads to illness. A deficiency of proteins and fats, especially the latter, is the chief characteristic of the dietaries of communities, notably of armies, public institutions, and the poorer classes in general. Any marked diminution in the amount of water taken as food leads to deficient tissue activity, giving rise to undue retention or storage of water in the body, especially in the muscles, with the establishment of defective health and disease-resisting power.

Associated with defects in the supply of the vitamines in a dietary are a number of diseases often referred to as deficiency diseases. Some, like rickets and dwarfism, occur mainly in the young, while others, such as scurvy, osteomalacia, pellagra and beri-beri may occur in both young and adult persons. In each case the essential cause is a defective dietary involving either a deficiency or an absence of the necessary protecting vitamine from the constituent elements of the diet. Thus, the absence of the water soluble anti-neuritic accessory factor or vitamine from the dietary of people living mainly on de-corticated rice is the cause of beri-beri and the poly-neuritis of the tropics. The reason is that the essential vitamine exists in the inner coat of the rice grain, and if this coat be removed in the preparation or milling of the rice, the consumers of that rice ultimately develop the disease. Badly prepared or an insufficiency of whole milk in the

feeding of children is the cause among them of scurvy, rickets, osteomalacia, and dwarfism, because the necessary fat-soluble and water-soluble vitamines normally present in good whole milk and its preparations are absent from the diet. Scurvy in adults results from a similar sequence of events or absence of the necessary protective vitamines from their food; but in their case it is not so much a deficiency from the milk element in the dietary but rather a defect in the other constituents of their daily food, which is generally found to have consisted mainly of salted or preserved meat, biscuits, and dried or preserved vegetables. These deleterious effects are not due to putrefactive or bacterial decomposition in the food stuffs, but simply to the destruction or absence of the vitamines in what may be called devitalized food. This devitalization or material departure from the fresh condition may be the result equally of faulty preservation, caused by exposure to undue heat and drying or desiccation, as to prolonged keeping: in other words, the more the constituents of a dietary depart from the fresh condition, and the more prolonged the period over which the consumption of such devitalized food extends, the greater are the probabilities of a development of scorbutic symptoms or signs of other deficiency diseases among the consumers. We need to remember that the absence of a specific factor or factors such as the vitamines from the food produces results very different from those that follow starvation. In the latter the actual requirements and other demands are met from the tissues, and there is economy of effort and material. Some harmony among all the processes is secured. But when an individual's diet is deficient in, say, a vitamine, he may still be dealing with large quantities of total food. The truth is, the necessary vitamine supply is quantitatively not independent of the amount of diet as a whole, nor even of its character. For example, an excess of carbohydrate in the food may exaggerate the effect of a deficiency in the fat soluble vitamine: not from any added toxic effect, but because it reduces the consumption of body fat and therefore the mobilization of the store of vitamine which exists in the fat depôts. On the other hand, the stimulus to metabolism or tissue change produced by an excess of protein might exert an influence in the opposite sense. Modern knowledge has extended the conception of specific functions in nutrition: functions which are independent of energy supply or mere expressions of so much protein, fat, or carbohydrate.

Meat.—Although in different parts of the world, the flesh of various kinds of animals is eaten as meat, that chiefly used is beef from the ox, veal from the calf, mutton from the sheep or goat, and pork from the pig. To these may be added the flesh

of fishes. As an article of diet, meat furnishes proteins, fat, and salts. A general analysis of meat yields roughly in a hundred parts 75 of water, 20 of protein, and 5 of fat. The protein is for the most part myosin, which exists in the muscle fibres. This myosin is, strictly speaking, a globulin, soluble only in saline solutions or dilute acids and alkalies. It is the result of the coagulation of the muscle after death, this coagulation constituting the so-called *rigor mortis*; in this state meat is tough, but when the *rigor mortis* has passed off, the meat becomes tender. The coagulation of the myosin is due to the presence of sarcolactic acid. Besides myosin, meat contains other proteins such as small quantities of alkali and serum albumin, also a globulin from blood. Of the total proteins in ordinary meat some 13 per cent. are made use of in the body, and possibly even more in the best samples. The amount of fat in meat of course varies; it usually solidifies after death, and in bacon consists chiefly of oleates, in beef of palmitates, in mutton of stearates—these respective kinds of fats being soft and fusible in the order named. It is from these animal fats that the best margarine is made. In good ox flesh about 33 per cent. is fat, in pigs about 50 per cent., in calves about 16 per cent.; in thin or badly fed animals, the fat may be as low as 1 per cent. of the meat.

The mineral salts of meat are chiefly phosphate of potassium with small quantities of magnesium, calcium, and chloride of sodium. Besides these, meat yields certain nitrogenous crystalline bodies, called commonly *extractives*. These are derived from the changes in the protein of muscle, and constitute the stimulating principles of beef-tea and broth. The chief extractives of meat are kreatin, kreatinin, xanthin, taurin, sarkin, and urea. In estimating the dietetic value of meat some allowance must always be made for bone, which, as usually sold, equals at least $\frac{1}{5}$ of the whole, but this is a much less variable item than the fat.

Constituting as it does so large a proportion of the food of man, a proper inspection of meat intended for food is of the first importance, especially with a view to the detection of whether it be fresh and free from putrefactive changes, and too, whether it be wholesome and sound, and not derived from a diseased animal. It is rare for any one to have opportunities of examining the live stock intended for meat before slaughter. Should such occur it is important to remember that the signs of a healthy animal are, being well nourished, able to rise without difficulty and to walk without lameness. Its coat should be bright and glossy, and free from scabs, boils, or sores. The eyes of the animal should be bright, with mouth and nostrils moist yet free

from discharge. The breathing should be quiet and easy, and the breath free from odour.

Inspection of Meat.—Good and healthy butcher's meat is firm and elastic to the touch, moist, but not wet; if well fed, marbled in appearance, from small layers of fat between the muscle fibres. Except in the case of veal and pork, good meat is of a bright red colour. On standing awhile, a red juice oozes out; this should be faintly acid. There should be a fresh but not unpleasant smell. The fat should be firm and whitish yellow in colour, and free from blood-stains. If putrefaction has occurred, the meat is soft, pale, and usually offensive; if a knife or skewer be thrust into such meat and rapidly withdrawn, it will smell offensively. The juice, too, is usually alkaline, and fails to redden blue litmus paper. Occasionally horseflesh is offered for sale in place of beef. Owing to the bones of the horse and ox differing so much one from the other, horseflesh is usually boned before being offered for sale as beef. It is also more oily than beef, and moreover coarser and darker, without the fat layers in the muscle; it has, besides, a characteristic odour. At times, peculiarities of fodder or pasture may give a disagreeable odour to meat, but it is exceptionally rare for any distinct ill effects to result from eating such. Similarly, the meat from animals recently physicked may be less palatable, and is of course proportionately deteriorated in quality. At other times meat may be coarse, tough, and stringy, especially if the animal be aged; such meat should not be regarded as unfit for food simply on account of age. A cow may be slaughtered as late as twenty years of age, though in such a case the carcase would be extremely thin. The best beef is from oxen of from five to six years of age. As sheep are not used for milking in this country, aged ewes are rarely seen in the meat markets; old rams, however, are by no means uncommon, yielding, of course, poor mutton. Ram mutton is coarse, and often emits an unpleasant smell.

Diseased Conditions of Meat.—The flesh of over-driven animals is said to be injurious, but perhaps the most common condition which renders flesh unfit for human consumption is putrefaction. In marked emaciation from disease, but not mere leanness, in glanders, anthrax, generalised tuberculosis, measles and trichinosis, the whole carcase of the animal should be condemned. Local inflammatory conditions, early and limited actinomycosis, localized tuberculosis, or the presence of liver fluke and echinococci do not justify the condemnation of the whole carcase, if the rest of the flesh is firm and of good colour. In these cases, it will suffice to cut freely away on the diseased parts.

The following are the chief diseases met with or likely to occur

in either home-bred or imported animals, and which may be regarded as more or less rendering their flesh unfit for man's food:—

In oxen and sheep:
- Cattle plague.
- Pleuro-pneumonia.
- Anthrax
  - Boils.
  - Black quarter.
  - Splenic fever.
- Sheep pox.
- Consumption (tuberculosis).
- Actinomycosis.
- Joint-ill or rheumatism.
- Foot-and-mouth disease.
- Liver-fluke.
- Hoof-rot.

In pigs:
- Pleuro-pneumonia.
- Swine fever.
- Anthrax.
- Foot-and-mouth disease.
- Consumption (tuberculosis).
- Quinsy.
- Cysticerci (measles).
- Trichinæ.

In horses:
- Glanders.
- Farcy.

A few of these affections are parasitic diseases in which the meat or flesh is infected with the young of worms so as to render it unfit for the food of man. With regard to the hurtfulness or not of the flesh of animals affected with general diseases, some variety of opinion exists. The general symptoms resulting from the consumption of such meat are mainly vomiting, diarrhœa, fever, and more or less prostration. In the majority of cases of disease, the meat is dark and moist, usually altered in consistency.

Although there is reason to think that, with few exceptions, harmful products in the flesh of animals which have died from any diseases such as cattle plague, pleuropneumonia, foot and mouth disease, rheumatism, glanders or farcy are rendered innocuous by exposure to the temperature of cooking, still the safest course is to reject for food the flesh of all animals affected with any acute or specific disease. The great majority of outbreaks of "food-poisoning" are due to infection of the food with bacilli of the Gartner group, a class of bacilli closely related to those of dysentery and enteric fever in man. The diseases of animals caused by or closely allied to infections by bacilli of the Gartner group are swine fever and certain septicæmias and dysenteric diseases of calves and cattle. Sometimes these outbreaks of food-poisoning are instances in which the infecting bacilli have reached the meat or food from outside sources, that is either by contamination by "carriers" of infection, either human or animal, or by fouling by rats or mice suffering from *typhus murium*, a disease in which the infecting bacillus belongs to the Gartner group. Putrefactive changes in meat were once thought sufficient to account for illness associated with outbreaks of food-poisoning. This is not the case, and what is so often called ptomaine poisoning is now recognized to be due to infection with the Gartner bacilli, the bacilli themselves producing toxins or

diffusible poisons which are the cause of the illness. These toxins are little if at all affected and modified by cooking. Frequently the mischief is done after cooking and during handling and storage.

Owing to its widespread diffusion among animals killed for food, tuberculosis or consumption is a constant source of danger to meat consumers. Commonly called by butchers "the grapes" or pearl disease, it is common among oxen and pigs but less so among sheep. The disease is marked by the presence of small white tumours or pearls. These occur mainly on or near the surface of the lungs and on the inside of the chest walls, but they may also be scattered through the lungs, liver, and general parts of the body; this latter condition is rare. Tuberculosis is now known to be associated with, and caused by a minute organism called the tubercle bacillus, which is readily carried from one part of the body to another, and consequently is a disease communicable from one of the lower animals to man. The Royal Commission on Tuberculosis (1898) advised that the entire carcase and all organs should be seized in case of—

(1) Miliary tuberculosis of both lungs;
(2) Tuberculous lesions on the pleura and peritoneum;
(3) Tuberculous lesions in muscle or intermuscular lymphatic glands;
(4) Tuberculous lesions in any part of an emaciated carcase.

But only the tuberculous parts need be seized if the lesions are confined to—

(1) The lungs and thoracic lymphatic glands;
(2) The liver;
(3) The pharyngeal lymphatic glands;
(4) Any combination of the above if the lesions are collectively small in extent.

They also advise that foreign dead meat with "stripped" pleura should be seized; and that in the case of the pig the whole carcase and organs should be seized if tuberculous deposit in any degree be found. These views have been confirmed by the Report of the Commission in 1907.

Mention has already been made that the flesh of animals used as meat is frequently affected with parasites. In oxen—that is, in beef—the parasite, present occasionally, is what is called the *Cysticercus bovis*. It consists of a head or scolex of a tapeworm having attached to it a cystic expansion. Meat containing this cysticercus gives rise in man to a tapeworm called the *Tænia mediocanellata*. A detailed account of this parasite and its life history is given in a subsequent chapter. One of the most common hydatids is the *Echinococcus veterinorium*. This is the

hydatid of the tape-worm *Tænia echinococcus* which inhabits the intestines of the dog. These cysts may be localized in any organ of the body, but most largely in the liver. The *cysticercus tænia-collis* or hydatid form of the *Tænia marginata*, which is the tape-worm of dogs, is often found in large numbers in the abdominal cavity of sheep and pigs. These cysts vary in size from a pea to a tennis ball, and are found usually adhering to the folds of the peritoneum. Sheep also suffer from the hydatid or cystic form of the *Tænia cænurus*, which also inhabits the intestines of dogs, and is the one which gives rise to the condition known as "sturdy" in sheep. It is usually lodged in the brain of the sheep. Unless the animal be much emaciated, the carcase of the animal with the exception of the head is fit for food.

In sheep, the chief and most common parasite is the *fluke*, which is a kind of worm, in shape very like a sole fish, only measuring 1 to $1\frac{1}{2}$ inches in length and about $\frac{3}{8}$ inch in width. It infests the liver of sheep and occasionally oxen, giving rise to the disease of sheep called "the rot." As cooking always kills the fluke, few cases of disease from this parasite are known in man; but as its presence in a sheep's liver usually causes the animal to be in bad health, the flesh of "rotted" sheep must, as a rule, be regarded as unsound and unfitted for food. Occasionally, both oxen and sheep are affected with the cyst form or cysticercus of the *Tænia echinococcus*, which is a tapeworm whose adult form only affects dogs and wolves. In man, this cyst gives rise to echinococcus or hydatid disease. A more detailed account of this parasite is given in Chapter VIII.

The presence of cysticerci in meat is generally visible to the naked eye; they are so numerous sometimes as to cause the flesh to crackle on section, or even feel gritty: their real nature is readily seen when the meat is placed under a microscope with low power.

The pig is infested with two parasites, both of which exist in the flesh or pork. One is the *Cysticercus cellulosæ*, which, existing in the pig's muscle as a cyst of the size of a pea or small marble, constitutes the affection known as "measles," and this measly pork when eaten gives rise to a tapeworm in man called the *Tænia solium*. The cysticerci of pork are killed by a temperature of 140° F., and if pork were always properly cooked this would render them harmless; but as no dependence can be placed upon the meat being sufficiently heated and cooked, measly pork needs to be always condemned as unfit for food. The other parasite of the pig is the *Trichina spiralis*. This is a very small immature worm, which is found coiled up inside ovoid cysts, which, of the size of $\frac{1}{70}$ inch, lie imbedded in the pig's muscle. When thus

affected, the pork shows a number of small white specks between the muscle bundles, and is said to be trichinosed. As will be explained subsequently, the eating of this trichinosed pork gives rise to the disease called trichinosis in man. Such diseased pork is, of course, unfit for food. *Pimply gut* is characterized by the presence in the wall of the small intestine of the pig of small round dark-coloured nodules. Each nodule contains the larvæ of the round worm *Œsophagostomum columbianum*. The condition is important, chiefly in connection with the use of sausage skins.

Onchocerciasis is a condition due to a worm known as the *Spiroptera reticulata*, and has recently been found in Australian meat imported frozen into this country. The parts of the carcase generally found to be affected are the fore quarter, the brisket, and the hind quarter. The nodules are oval, about one inch in length and half-inch wide, and are formed by the *Spiroptera*, which probably are introduced by a biting insect. The worm does not long survive the death of the host, so that infection to man is not probable.

Fish.—As a class, fish vary much in digestibility, this depending practically on the amount of fat they contain. The fatter a fish is the more digestible its flesh. Of the fat group of fishes the best are salmon, herring, mackerel, eels, and sprats; of the non-fatty, the cod is the most commonly consumed specimen. Of the various shell-fish, oysters eaten raw are almost self-digestive, but lobsters and crabs are not only foul feeders, and as such liable to give rise to ill effects when eaten, but also notoriously indigestible. The same may be said of mussels, these fish in particular being at times extremely liable to cause poisonous symptoms, especially when taken from stagnant water to which sewage has access.

To be at their best and wholesome, fish should be in season. During spawning a fish gets flabby and thin, and during this period is rightly regarded as being "out of season" and unfitted for food. A few fish are peculiar in their breeding, such as brill, dory, lobsters, plaice, prawns, soles, shrimps, turbot, and red mullet, which are in season all the year round. Oysters are not in season during the four months spelt without an *r*.

By the Freshwater Fisheries Act, 1878, it is enacted that, subject to special exemption by the Board of Trade for eels, pollen, trout, and char in certain fishery districts, from March 15 to June 15 shall be a close time for all fresh-water fish.

As in the case of animals, fish when eaten should be fairly fresh. A fresh fish is firm and stiff; the drooping or not of its tail is a fair criterion of freshness in a fish. Flat fish keep better

than herrings or mackerel. Cod, haddock, and whiting keep the best, particularly if rinsed with salt water and stored in a cool place. All fish intended for food should be unbruised, unbroken, and clean. If the scales are dull and damaged, it is very suggestive of either ill usage or staleness; softening in places indicates the same. Fish are sometimes affected with a parasite in the form of a cysticercus. This, when eaten imperfectly cooked, gives rise to a tapeworm called the *Bothriocephalus latus*. These diseased fish are rare in this country, but common in Russia, Poland, Sweden, and Switzerland.

Although the great group of fishes yields a larger number of species used as food by man than either birds or animals, and although there are but few fish in British waters which may not be eaten with advantage, still many prejudices exist with regard to their use. This is much to be regretted, as fish are most valuable and important articles of nourishment; if perhaps not possessing the satisfying and stimulating properties that belong to the flesh of birds and quadrupeds, still the health and vigour of the inhabitants of fishing towns, where fish often forms the only kind of flesh food consumed, show that it is capable of maintaining the body under active conditions of life. The fish-eating races and classes are remarkably strong and healthy. For the sick or weakly, in whom the powers are too feeble to digest the stronger kinds of animal food, fish possesses valuable properties.

The processes of drying, pickling, salting, and smoking are employed for the preservation of fish. Each process considerably lessens its digestibility, and therefore unsuits it for either the dyspeptic or the invalid.

Eggs.—From the fact that the young chick is developed from it, an egg necessarily contains all that is required for the construction of the body. On this account eggs are often spoken of as typical natural foods. Protein matter is largely present, under the form of albumin, both in the white and yolk. Fat exists as an oil in the yolk. Carbohydrates exist in the form of minute quantities of a saccharine matter, and water and salts complete the list. The hen's egg usually weighs 2 ozs., but those of ducks and some sea-fowl weigh more. The shell of an egg constitutes some 10 per cent. of the total weight; the white, 60 per cent.; and the yolk, 30 per cent. The white of egg consists chiefly of albumin, with traces of fat and salt; the yolk consists largely of fat and salts, with a small amount of globulin. Ducks' eggs contain generally more fat than those of hens. Eggs offer a convenient and concentrated article of diet, rich in fat and protein, but are at times indigestible, particularly if overcooked.

They are conveniently preserved by exclusion of their contents from the air by immersing them in lime water or "water glass" (silicate of soda). Their condition as to freshness is readily determined by dissolving 2 oz. of common salt in a pint of water; in this solution a good egg will sink, while a stale or bad one floats. Eggs may also be examined by looking at them in the dark against the strong light of a lamp. A fresh egg appears unclouded and almost translucent; a bad one is opaque and dark.

Milk.—Milk not only constitutes the chief diet for children up to some eighteen months of age, but also enters very largely into the food of adults. All milk may be regarded as nothing more than an emulsion of fat containing proteins, salts, and carbohydrates in solution in water. The average composition of milk per 100 parts, from the chief sources as used by man, is shown in the following table:—

Kind of milk.	Specific gravity.	Total solids.	Proteins.	Fats.	Carbohydrates.	Salts.	Water.
Human . . .	1027	12·60	2·29	3·81	6·20	0·30	87·40
Cow's . . .	1032	12·83	3·55	3·69	4·88	0·71	87·17
Mare's . . .	1035	9·21	2·00	1·20	5·65	0·36	90·79
Ass's	1026	10·40	2·25	1·65	6·00	0·50	89·60
Goat's . . .	1032	14·30	4·30	4·78	4·46	0·75	85·71
Buffalo's . . .	1032	18·60	6·11	7·45	4·17	0·87	81·40

Although all the above are used at times by man for food, the most important kinds undoubtedly are human milk and cow's milk; and these differ from each other in some essential particulars. As seen by the preceding table, while there is more carbohydrate in human milk than in cow's, the reverse is the case with the proteins and salts; the fat being much the same in them both. Ass's milk, except in regard to its fat, is most like human milk, but mare's milk contains even less fat and protein than the ass's; while, on the other hand, milk from both the goat and buffalo are very rich in fat.

The proteins of milk consist largely of casein; but there is also some albumin, with traces of globulin. The casein probably exists in milk in combination with phosphate of lime, which helps to keep it in solution. Pure casein is now prepared on a large scale, and constitutes the basis of a number of dietetic preparations, such as Plasmon, Protene flour, Sanose, Nutrose, and Eucasin. The nutritive value of these preparations is high, as they contain fully 90 per cent. of pure protein. In these forms

casein is digested easily, and capable of replacing all other forms of protein in the diet.

The salts of milk are both numerous and various, being composed really of all the mineral constituents necessary to the growing body.

The fat of milk is nothing more than minute oil globules suspended in the milk, and which, upon standing, rise slowly to the surface, forming cream. One part of cream is said to correspond to 0·2 of fat roughly; the proportion of cream yielded by a pure milk varies, but may be said to average 10 per cent., being as high as 14 in some cases, and as low as 6 in others. The amount found in a given time is no measure of the richness of the milk; water added to milk causes a more rapid separation of the cream. When milk is subjected to centrifugal action, as in the *separator* so largely used now in commercial dairies, a much larger proportion of cream is obtained than by the mere skimming process. As a result of this, skim milk contains 1 per cent. of fat, while separated milk has practically none.

The carbohydrate of milk is a peculiar sugar, somewhat like cane-sugar, and called lactose, or sugar of milk. This body, like all other sugars, undergoes fermentation under the influence of micro-organisms, and one especially, called the *Bacterium lactis*, abounds in dairies and other places where milk is kept. This micro-organism converts the milk-sugar into lactic acid, while at the same time the proteins are partly decomposed and partly coagulated, the milk itself becoming sour with enclosure of the fat in the coagulated casein. Many other micro-organisms produce coagulation of milk, notably the *Bacillus butyricus* of butyric acid fermentation. Some others have the power of changing the colour of milk, particularly if lactic acid fermentation has occurred. In nearly all these cases the milk becomes ropy and stringy, also it is apt to cause diarrhœa, and is unsuited for food. Alcoholic fermentation of the milk-sugar can also be set up by certain micro-organisms. "Koumiss" is the result of the alcoholic fermentation of mare's milk, and "Kefir" is that of cow's, goat's, and sheep's. After the lactic acid fermentation of milk has set in, the casein gradually decomposes, and, during the early decomposition of the proteins, very frequently highly poisonous compounds are formed, such often being the cause of the violent poisonous effects which at times are produced by ice-creams and other articles of food into the making of which milk enters.

Humanized cow's milk is much used in the feeding of infants. Its essential feature is the removal of the excess of caseinogen from the cow's milk while retaining the soluble and easily digested

lact-albumin. A suitable method of preparation is: allow a pint of milk to stand in a cool place for three hours, then remove by skimming the cream which has risen to the top. Divide the skimmed milk into two equal parts. To one part add a small piece of rennet and strain off the curds when formed, leaving the whey. Heat this whey to 150° F., to destroy the rennet ferment, then add the other half of the skimmed milk and the cream. Add 175 grains of lactose or milk sugar to the mixture and sufficient lime-water to render the whole faintly alkaline. Then heat to 158° F. for twenty minutes. The use of whey in this method makes a better emulsion with the fat (cream) than ordinary water and also yields a fine curd.

Although boiling undoubtedly destroys bacteria and other micro-organisms in milk, it affects seriously the physical and nourishing qualities of this food. Boiling of milk produces coagulation of the lact-albumin, some obscure changes in the sugar, and greater coalescence of the fat globules; at the same time, the proteins are modified, and rendered apparently less digestible, the salts are less soluble, and the vitamines are destroyed. The chief chemical change in the salts is probably the conversion of the soluble bi-citrate of calcium into a less soluble tri-citrate. Most authorities agree that boiled milk has less nutritive value than that which is fresh, and that the indiscriminate feeding of infants for months upon carelessly boiled or heated milk is productive of much harm. A discrimination needs to be made not only as to means of heating milk, but also between degrees of heat to which it is raised. It is known that up to 70° C. no apparent changes are produced in milk; at 70° C. the albumin begins to be affected, not actually coagulated, but converted into a form which is easy of precipitation by acids, sulphate of magnesium, and other precipitants of casein. At 80° C. milk tends to alter in flavour and the vitamines undergo retrograde changes; at 85° C. the calcium citrate is thrown out of solution. The remedy seems to be to avoid routine boiling of milk, but to heat the milk in a water bath or *bain-marie* to not more than 75° C. (160° F.), maintaining it at that temperature for twenty minutes or so, and then cooling it to a temperature as near 15° C. (32° F.) as possible. This is the method of so-called "pasteurization." It may entail more trouble for mothers and nurses, but the recognition of the principle is the only basis for sound practice, provided that it be borne in mind that the *pasteurized* milk has somewhat lessened keeping properties than the untreated milk.

The actual composition of cow's milk is influenced by not only the breed of the animal, but also by the kind of feeding

and the time of calving and milking. The effect of diet is largely shown by the increase of sugar found in the milk of cows fed upon fodder rich in carbohydrates, such as carrots and beetroot. The addition of protein in the diet raises the casein, but not the fat. The colostrum, or milk of cows recently calved, is poor in sugar, but rich in casein and albumin. The first part of a yield during milking, known as fore milk, is deficient in fat, but the latter part, called the strippings, is very rich in cream.

It is well known that in human beings, bitters and purgatives, if taken by the mother, act upon infants taking the milk. Diseased potatoes and turnips in the food of cattle, without actually affecting the goodness of milk, often cause it to smell and taste unpleasantly; other fodders often produce poisonous effects, as in goats feeding upon meadow saffron inducing severe diarrhœa, or in the case of cows affected with "trembles," due to eating the *Rhus toxicodendron*, their milk gives rise to vomiting and constipation. Milk allowed to stand long in warm dirty rooms has a remarkable power of absorbing bacteria, rapidly becomes sour and objectionable, and is a fruitful cause of diarrhœa occurring among the children of the poor.

Milk may be affected by diseased conditions of the cow or the animal yielding it. In foot-and-mouth disease, cow's milk varies very greatly; but a constant feature of such milk is the great excretion of serum albumin. Milk of cows affected with foot-and-mouth disease should never be consumed as food, as it may cause disease in human beings. Tuberculosis in cows undoubtedly affects the milk yielded by them, particularly when the teats are tuberculous, and such milk, if consumed, is the undoubted cause of infection by the same disease (consumption) in man. There is much to suggest that a considerable amount of tubercular infection through milk takes place in infancy and early childhood. There is reason, too, to think that both scarlet-fever, diphtheria, and enteric fever, and also cholera, are in many cases propagated by means of milk, the milk becoming infected, either by foul water used in the cleaning of utensils or for intentional dilution, or by handling by human beings who were or are at the time sufferers from one or other of these diseases. The remedy is obviously to subject any doubtful milk to pasteurization or to a temperature of at least 70° C. for twenty minutes, as by this procedure the specific micro-organisms of tuberculosis, diphtheria, enteric fever, dysentery, cholera, zymotic diarrhœa and other infective diseases are destroyed.

Adulterations of Milk.—The chief adulterations of milk are the additions of water and the removal of cream; while carbonate of soda, salt, formaldehyde, boracic acid, or salicylic acid, glycerine

and starch are added, either to preserve the milk or to mislead the analyst. A common procedure is to remove part of the cream, a procedure which would naturally raise the specific gravity, and then, by adding water, to bring the specific gravity down to the normal. The addition of water lowers the specific gravity, the fat, solids not fat, and the salts per cent. This added water can be sometimes detected by taking the specific gravity of the milk by means of a lactometer, which should be done at a temperature of 60° F.; if at a higher or lower temperature than this, 1° of specific gravity must be added or deducted for every 10° of heat. In good milk, the specific gravity is from 1028 to 1034; while, in creamed milk, it is from 1033 to 1037; that is to say, it is lowered by watering and increased by skimming. This taking of the specific gravity alone is not to be relied upon as an index of the character of the sample, but should be taken in conjunction with the facts relating to the fats and total solids.

The total solids can be estimated by taking a weighed quantity of milk, and evaporating it slowly to dryness, and re-weighing. Usually 2·5 c.c. of milk are taken for this estimation, and in good milks the total solids should not be less than 12 per cent. The fat in a good milk should not be below 3 per cent.; it is conveniently estimated by mixing a weighed quantity of milk with a weighed amount of burnt gypsum, and evaporating to dryness. The fat is extracted from the residue by ether, and the ether then evaporated, when the residue is again re-dried, re-weighed, and calculated out as fat per cent. For the more rapid and routine estimation of fat in milk samples, the employment of a centrifugalizing machine and the use of the Leffmann and Beam process will be found satisfactory. Fifteen c.c. of the milk are placed in the special glass bottle supplied with the centrifugalizer; 3 c.c. of a mixture of equal parts of fusel oil and strong hydrochloric acid are added, and then 9 c.c. of pure sulphuric acid. These latter must be added slowly, about 1 c.c. at a time, and the contents of the bottle carefully shaken. The milk will gradually assume a chocolate colour passing to a deep brown, and at the same time much heat be generated. When the whole of the 9 c.c. of acid have been added, the contents of the tube or bottle must be filled up to the zero mark with a hot and freshly made mixture of one part of strong sulphuric acid with two of water. The bottle should be placed in one of the carriers of the machine, and whirled for at least two minutes. If only one sample of milk is being tested, the opposite carrier must be balanced by a corresponding bottle filled with dilute sulphuric acid. A milk poor in fat may need centrifugalizing for four or five minutes, but usually two minutes is enough: very rapid rotation is not necessary.

On stopping the centrifugalizer and taking the bottle out of the carrier, the fat will be seen to have separated out as a layer on the top, and as the bottle is so made that each mark represents 1 per cent. of fat, the total percentage of fat in the sample is readily read off. This method is subject to an error of about 0·1 per cent., but its rapidity and ease render it a valuable and reliable means of fat determination. The amount of fat so determined deducted from the total solids gives the "solids not fat," and as the result of many analyses, these are found, with very rare exceptions, not to fall below 8·5 per cent. Hence this amount is adopted as a standard, and if a given milk sample contains x per cent. of solids not fat, and x be less than 8·5, we are justified in presuming that, however poor the milk may have been to begin with, it must now have added water in it. Thus, presume a given sample of milk has yielded 3·5 per cent. of fat, and 10·5 per cent. of total solids. The solids not fat are obviously 7 per cent., and working upon the above-mentioned minimum standard of 8·5 for solids not fat, we get the following formula: $\frac{100 \times 7}{8{\cdot}5} = 82{\cdot}35$ parts of original or genuine milk in a 100; or, in other words, over 17 per cent. of water may be presumed to have been added to the sample. The ash of a good milk rarely falls below 0·7 per cent., and accepting that as a minimum standard, a similar equation can be stated, if the observed amount of ash be known, as a means of calculating the degree of purity of any particular milk. The ash of milk is, of course, estimated by incinerating the total solids of a given bulk of milk, weighing and expressing as a percentage.

Sugar in milk is easily determined by first precipitating the casein, by means of acetic acid, from 10 c.c. of milk; filtering, and then diluting the filtrate or whey with distilled water to 100 c.c. This diluted whey contains the lactose or milk-sugar in solution, and is next treated with a solution of copper until all the copper is reduced to red suboxide, and no blue colour remains in the liquid. The copper solution is so made that 10 c.c. are decomposed by 0·0667 grm. of lactose.[1] If, say, 15 c.c. of a ten-times diluted whey are required to reduce 10 c.c. of copper solution, then $\frac{15}{10}$, or 1·5 c.c. of the original milk are needed

[1] Take of pure copper sulphate 34·64 grms., and dissolve in 500 c.c. of distilled water; this is stock solution A. Take also 173 grms. of the tartrate of sodium and potassium, with 56 grms. of caustic soda, and dissolve in 500 c.c. of distilled water; this is stock solution B. When required for use, take 5 c.c. of each solution and mix. One c.c. of this solution is reduced by 5 mgms. of either glucose or inverted sugar; and by 6·67 mgms. of milk-sugar or lactose.

to reduce that amount of copper solution, and 0·0667 grm. lactose $\div$ 1·5 = 0·0445 grm. of lactose in 1 c.c. of milk, or 4·45 per cent.

The presence of added glycerine in milk can usually be detected by the exceptional sweetness of the dried solids, but for the detection of such preservatives as boric acid, salicylic acid, sodium carbonate, and formaldehyde in milk, the following tests need to be applied:—

Boric Acid.—Reduce 25 c.c. of the dried milk to an ash slowly in a capsule, add a few drops of hydrochloric acid, sufficient to render it distinctly acid, and then 25 c.c. of distilled water. Now dip strips of turmeric paper in the mixture and dry them over a flame. If boric acid be present the turmeric paper will turn a crimson red, which on the further addition of sodium carbonate turns blue.

Salicylic Acid.—Agitate 10 c.c. of the milk in a test tube with 0·5 c.c. of dilute sulphuric acid, so as to thoroughly break up the clot and produce a homogeneous mixture. Next shake with 10 c.c. of ether, allow this to separate, and transfer to either a capsule or another test tube; slowly evaporate the ether at say 75° C., and then dissolve any salicylic acid which may be present in the residue by boiling with 10 c.c. of rectified spirit. Now add some ferric chloride solution and shake. If salicylic acid be present a violet colour will be produced.

Sodium Carbonate.—Mix 10 c.c. of milk with 10 c.c. of rectified spirit in a test-tube, and then add two or three drops of a weak solution of rosolic acid, made by dissolving 1 grm. in 25 c.c. of alcohol, and diluting with distilled water to a litre. If the alkali be present in the milk, a rose-pink tint appears.

Formaldehyde.—Place about 10 c.c. of the milk in a test-tube, add to it 2 c.c. of a 10 per cent. solution of caustic potash and 1 c.c. of saturated solution of phloroglucine. If formaldehyde be present a fleshy pink colour is produced.

The question of preservatives in milk and milk products has long been a serious matter as affecting the national welfare. Opinion is divided as to the actual harm resulting from the use of very small quantities of preservatives in food, but modern methods of cleanliness, storage, and transit, if properly applied, should render the use of preservatives unnecessary even for so rapidly decomposable a food as milk. The practice of using preservatives in food leads to uncleanly methods, and is often the means of rendering saleable an unwholesome food. The P.H. (Milk and Cream) Regulations, 1912, prohibit the use of preservatives in milk, but define the conditions under which

preservatives may be used in cream. The expression "milk" includes separated, skimmed, condensed, and dried milk; but so as not to interfere with the trade in condensed milk, it is laid down that neither cane nor beet sugar shall be regarded as a preservative, or a thickening substance. The restriction on the use of preservatives in cream is as follows: "No person shall add or order or permit any other person to add any thickening substance to cream or preserved cream, or any preservative substance to cream containing less than 35 per cent. by weight of milk fat or to cream containing 35 per cent. or more by weight of milk fat any preservative substance other than boric acid, borax, or a mixture of these preservative substances, or hydrogen peroxide in amount not exceeding 0·1 per cent. by weight in any case in which the cream is intended for sale for human consumption." Dealers in cream preserved in a manner which does not contravene this regulation must attach a label to declare that the cream is preserved, and to state the name of the preservative. In tea-shops and refreshment-rooms the cream jugs are not required to be labelled, provided in each room a conspicuous notice is affixed indicating that the cream supplied is preserved cream, or if a statement to that effect is printed on the bill of fare.

An amending Order, 1916, allows boric acid to be added to cream containing more than 35 per cent. by weight of milk fat, provided the amount of boric acid so added does not exceed 0·4 per cent. by weight of the preserved cream. Every receptacle containing preserved cream must be labelled "Preserved Cream containing Boric Acid not exceeding — per cent. Not suitable for Infants or Invalids." These amending regulations have been in abeyance and will not take effect till 1921.

The Board of Agriculture under the Sale of Milk Regulations, 1901, laid down certain fixed limits or standards as to the composition of milk. By these regulations a presumption is raised that milk (not being sold as skimmed or separated, or condensed milk) is not genuine unless it contains 3 per cent. of milk fat and 8·5 per cent. of milk solids other than milk fat. Further, where a sample of skimmed or separated milk (not being condensed milk) contains less than 8·7 per cent. of milk solids other than milk fat, it shall be presumed that the sample is not genuine. By this order the principle of standards for food becomes officially recognized.

A number of excellent brands of *condensed milk* are now on the market. As a rule condensed milks are free from preservatives. In the sweetened milks the added cane sugar is sufficient to check the growth of bacteria, and in the unsweetened

varieties the milk has been sterilized at temperatures over 100° C., amply sufficient to destroy any disease causing micro-organisms. The full cream unsweetened condensed milks are the more suitable for feeding human infants, but, owing to the high temperatures to which the original milk has been exposed in manufacture of the condensed article, the essential rickets and scurvy preventing vitamines have been destroyed. We believe that this objection does not hold good for the various brands of *dried milk*, of which several are in general use. Only the full-cream dried milks should be used for infant feeding. We have reason to think that the best brands retain the essential vitamines so characteristic of the normal fresh milk of the cow. The dried milk powder keeps well if stored in a dry and properly ventilated place. The chief objection to the use of dried milk is the difficulty of reconstituting a satisfactory representation of the fresh article. It is by no means easy to make a good emulsion with water from dried milk powders, and until this difficulty is overcome there will remain always a certain objection to them. For travellers and others similarly situated, dried milk is an ideal article.

We cannot leave this subject of milk without calling attention to the urgent need of a reform of the country's milk supply. Associated as it closely is with the problem of infant mortality it constitutes a national question of the first importance. The problem of milk supply is really threefold, namely, (1) to prevent the sale of milk derived from tuberculous cows and to safeguard against initial pollution at the time of milking; (2) to protect milk from subsequent fouling, either during transit to or storage in the home of the consumer; and (3) it must be produced at a price which will bring it within the reach of the poor. To prevent the first, attention must be directed to the farm. The cows must be healthy, systematically inspected as to tuberculosis, and housed in byres or sheds so planned and constructed as to permit of these cattle remaining healthy. Further, the process of milking must be carried on with scrupulous cleanliness of cows, milkers, and all utensils. The second line of prevention must ensure that milk, immediately after milking, be maintained at a temperature not exceeding 40° F., and that as soon as possible after cooling the milk be bottled, and the bottled milk be kept at even a lower temperature, say 35° F., until it is delivered to the consumer. By the precautions during milking the initial contamination is minimized, and bottling would minimize home contamination. The third essential, or safeguarding of price, can only be obtained by the municipalization of the milk supply. The present position of the law, and details as to the legal

provisions existing already for controlling milk supplies, are given in Chapter XII.

Butter.—This really is the fat of milk clotted together, and consists chiefly of neutral fats mixed with water and small amounts of casein and salts. Average butter may be said to have the following composition per cent.: Fat, 78 to 94; curd, 1 to 3; water, 5 to 14; salt, 0 to 7. The flavour of a good butter is due to butyric and caproic acids, which constitute about 8 per cent. of the fat, the rest being composed of glycerides of oleic, stearic, and palmitic acids. The water in a good butter should not exceed 16 per cent., an excess lessens the keeping quality of the butter; it contains ordinarily in solution milk-sugar and the milk-salts. Milk-blended butters should not contain more than 24 per cent. of water. Common salt is usually present, but generally added after the butter is made. Artificial colouring matters are often present in butter, notably annatto, but it is harmless; occasionally starch is added to give weight, and may be recognized by its blue reaction with iodine. Practically the only adulteration in butter is the substitution of foreign fats, such as tallow, lard, palm-oil, rape-seed oil, or cocoa-nut oil, for milk fat; and as a result the analysis of a butter turns mainly upon the properties and composition of the fat.

The amount of fat can be estimated by dissolving it in ether, evaporating the ether solution, drying, and weighing. For the detection of an admixture of foreign fats, several methods have been proposed; the principal being: (1) Taking the specific gravity of the sample. That of water being unity, a pure butter usually has a specific gravity of 0·911 to 0·913; an adulterated butter one of 0·902 to 0·904; and an artificial butter one as low as 0·859 to 0·861. (2) Determining the melting-point of the fat after separation from the other constituents. The melting-point of pure butter fat is 95° F., but may vary; the addition of animal fats, such as lard, raises the melting-point, while vegetable fats, such as rape-seed oil, tend to lower it. (3) Determination of the fixed fatty acids. This, though rather a difficult process to do, is most generally relied upon. It is based on the fact that when saponified with a caustic alkali such as soda or potash, and then decomposed with hydrochloric acid, the individual fatty acids which go to make up butter are obtained. A certain number of these are soluble in water, and others are not, and it is owing to the insoluble fatty acids obtainable from butter differing in amount from those obtainable from other animal fats that pure butter can be detected from artificial, the figures being, that if the insoluble fatty acids are over 89 per cent. there is an admixture of foreign fat.

Of artificial butters there are several; but in their manufacture

they are very similar, consisting really of a certain amount of genuine butter mixed up with animal or vegetable fats, such as lard, rape-seed oil, etc. By the Butter and Margarine Act, 1907, all these artificial butters are ordered to be called and sold as *margarine*, while milk-blended butters must be sold under such names as will disclose their nature and amount of contained water. If made from pure animal fats, these artificial butters have as high a nutritive value as pure butter. The average melting-point is 86° F., and the insoluble fatty acids contained in them are usually as high as from 92 to 95 per cent., as compared with 88 or 89 per cent. in pure milk butter.

For adults, margarine is but little inferior in nutritive qualities to butter, but, being derived mainly from vegetable oils, it is greatly deficient in fat soluble vitamines normally present in animal fats, and, for this reason, cannot replace butter or dripping in the dietary of the young. Margarine makes a palatable substitute for butter as an article of diet, but it must not be sold as butter. It is less digestible than butter and frequently contains preservatives and colouring agents.

Cheese.—This is made from milk by the action of rennet, which is commonly derived from the fourth stomach of the calf. Cheese consists of coagulated casein, with varying proportions of fat and salts. The different qualities of cheese depend mainly upon whether they are made from pure milk, from skimmed milk, or from a mixture of skim and whole milk. Thus, Cheddar, double Gloucester, Cheshire, and some American cheeses are made from whole milk, while Stilton is made from whole milk to which cream is added. Dutch, Parmesan, Suffolk, and Somersetshire cheeses are made from skimmed milk. Cream cheese consists of the fresh curd which has been moderately pressed; it is eaten without being allowed to ripen. When a cheese is kept, it undergoes a change known as "ripening," which is essentially a decomposition, whereby the casein undergoes a fatty change, including the formation of lime salts of the fatty acids and the production of a soluble compound of phosphoric acid with casein, from the phosphate of lime usually present in milk.

As an article of diet, cheese is very useful, being particularly rich in both protein and fat; the only objection to it being its occasional indigestibility. Its adulterations are unimportant, the chief being starch, to give weight. On an average, the water in cheese ranges from 20 to 35 per cent., the protein from 25 to 50 per cent., the fat from 12 to 20 per cent., and the salts some 3 to 6 per cent. Cheeses usually contain small amounts of milk-sugar, lactic, and other organic acids. The richer kinds of cheese are very liable to form the seat of growth of certain animal and

vegetable organisms. The maggots or larvæ of a fly (*Piophila casei*) are well known, so also is the cheese mite, or *Acarus domesticus*. The mould on a cheese is composed of minute vegetable organisms of the fungus tribe; the red mould is caused by *Sporendonema casei*, and the blue mould by *Aspergillus glaucus*.

Vegetable Foods.—This large group, which includes a great number of articles of diet, is chiefly remarkable for the fact that although it supplies a certain quantity of protein and fat, its chief functions are for the provision of carbohydrates, vegetable acids, water soluble vitamines, and salts to the organism. Further, owing to the large amount of water which vegetable foods take up during cooking, they may also be said to supply a large quantity of water to the body. The proteins of vegetables are mainly in the form of globulins and albumoses; the most important of them being *glutin*, which is largely present in wheat-flour. Glutin does not exist as such in wheat-flour, but is formed from the globulin and albumose, naturally present, by the action of water. Glutin being readily digested, forms a very valuable protein food; it can be obtained also from rye-flour, but less easily than from wheat. *Legumin* and *conglutin* are other proteins found chiefly in the Leguminosæ, or peas and beans. These proteins are like glutin, derived by the action of water from the globulin and albumose present in the grains. The fats yielded by vegetable food are very small in quantity, and, from a nutritive point of view, quite unimportant.

The carbohydrates, either as starches, gums (dextrine), or sugars, constitute the chief part of all vegetable foods. In the cereals, potatoes, peas, and beans, starch is the chief carbohydrate, coupled with small quantities of sugars or dextrines. In beetroot and sugar-cane, of course, cane-sugar is the carbohydrate, while in the ripe fruits it exists in the form of glucose or grape-sugar. The starches are a large class, and vary as much in the size, form, and structure of their grains as they do in their origin, which embraces not only wheat, oats, barley, rye, maize, peas, beans, and potatoes, but includes the various forms of arrowroot, tapioca, and sago. In its uncooked state, a starch grain is hard and not easily digested; it is composed of two bodies called *granulose* and *erythrogranulose*, enclosed in cellulose coverings. Granulose, which constitutes the greater part of the starch grain, turns blue with iodine, the erythrogranulose turns red with the same, while the cellulose is turned yellow by iodine. Moist heat causes the cellulose coat to burst, so that the grain swells up and the starch is set free. Starch grains have in the majority of cases a sufficiently characteristic appearance, under the microscope, to

indicate their origin, and it is upon their peculiarities of size and form that the various adulterations of the starches by other kinds is best detected. Wheat-flour being the most important, is the kind most usually adulterated with other varieties of starch. To examine a starch under the microscope, it is sufficient to moisten a little of it in a state of fine powder with a drop of water or glycerine upon a glass slide. When so examined, they can be conveniently divided according to their appearance into two groups: (1) a group in which their contour is even; this includes wheat, rye, barley, pea, bean, the arrowroots and potato; (2) the other group is one in which, instead of the contour being even, it is marked by facets or surfaces, either completely, as in oats, maize, and rice, or only partially so, as in tapioca and sago. The chief characteristics and appearance of the various starches will be noted in the subsequent figures.

The vegetable foods as a class yield excessive quantities of phosphates and potash as compared with the animal foods, which are particularly rich in chlorides and soda; on this account, common salt or chloride of sodium is a special need among vegetable feeders. Iron is usually present in most cereals, particularly in wheat, in which it exists mainly as a phosphate.

Wheat which is grown in this country is a kind known as *Triticum vulgare;* the grain is surrounded by four coats, each of which is composed of special shaped cells. Within these coats is the grain proper containing the starch, fat, proteid, and salts. The starch grains of wheat (Fig. 17) are very unequal in size, some being very large, and others small; the large ones have a central spot, or hilum, and are marked by faintly concentric rings; the smaller ones are often angular. In the process of milling, the various coats of the wheat grain are more or less removed and separated as bran, the inside of the grain being ground up so as to constitute flour of the best quality. In the second-rate flours, this separation of the bran is less perfectly carried out, the result being a wholemeal flour of a dark colour. Wheat-flour is rich in protein and carbohydrate, but poor in fat and salts. Its protein, as already explained, exists as a globulin and an albumose, and from these, by the action of water, glutin is formed. The amount of glutin obtainable from a flour is a test of its quality and suitability for bread-making; usually this amount is

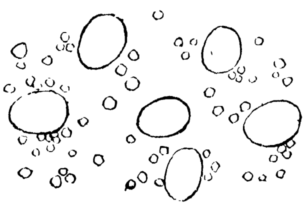

FIG. 17.—Wheat starch.

from 8 to 12 per cent. Its contained water should not exceed 16 per cent.; the more water present, the less the keeping quality of the flour; the salts are chiefly phosphates of potash and magnesia. A good flour should be white in colour and free from mouldy smell or acidity. It is occasionally adulterated by mixture with other starches, notably potato and rice starch; these can be readily recognized with the microscope. Both animal and vegetable parasites occur in flour, and can usually be detected by microscopical examination. The more common animal parasites are the weevil (*Calandra granaria*), the mite (*Acarus farinæ*), and one or more kinds of moth belonging to the micro-lepidoptera. The commonest vegetable parasites of flour are various fungi; one called *Puccinia graminis*, constitutes mildew or red rust of wheat, and whose ripe sporangia show themselves under the microscope as dark-brown club-shaped bodies filled with spores; another parasite is bunt, caused by the *Tilletia caries*, which microscopically appears as round reticulated cells. Another fungus, called *Ustilago segetum*, causing smut, is more common in barley or oat-flour than in wheat. Its spores or seeds are smaller than those of bunt, being also circular, nucleated, and not reticulated. The chief preparations of flour are bread, biscuits, macaroni, and vermicelli.

Bread.—The best bread is made from white wheat-flour, but brown and wholemeal breads are made from flours which contain more or less of the bran or wheat-grain coats. The disadvantages of wholemeal bread are, first, its dark colour, and next, the irritating and indigestible qualities of the cellulose of the bran. On the other hand, if we take bran as forming 16 parts of the grain, we have an addition to the bread, by inclusion of the bran, of some 0·7 per cent. of protein and 0·16 per cent. of salts.

Bread is made by mixing flour with water and kneading it so as to form dough by the cohesion of the glutin. To this dough is added a ferment or leaven, usually consisting of a mixture of potato, flour, and brewer's yeast. The addition of this leaven gives rise to a ferment action on the starch, whereby alcohol and carbon dioxide gas are formed in the dough, resulting in the latter becoming broken up and perforated by innumerable holes. During baking, a certain quantity of sugar and dextrine is formed from the starch, while too, in consequence of the full aeration of the dough, the bread mass becomes light and digestible. In some bakeries, in place of using leaven or yeast, powders consisting of tartaric acid and bicarbonate of soda are added in order to generate the necessary carbon dioxide. In another system the carbon dioxide is generated separately and the gas forced into the dough

by pressure. It is claimed for these unfermented breads that they have the advantage of containing no alcohol, acetic acid, and other bodies, the products of yeast action. This may be the case, but, on the other hand, the action of yeast is largely a digestive one, by which the starch is changed into maltose and dextrine, and some of the proteins into albumoses, or even peptones.

A good bread should be white in colour; any yellowness is suggestive of either an old flour, bad yeast, or a mixture of rye or bran. The acidity of bread should not exceed 0·18 per cent., and the whole loaf should be permeated in every part with small regular holes. Its contained water should not exceed 50 per cent., nor the ash be over 3 per cent. Alum is occasionally added to bread to improve the colour and check fermentation, any excess over 10 grs. per 4-lb. loaf being regarded as an adulteration. It is roughly detected by pouring upon a slice of bread some freshly made decoction of logwood chips and then a solution of carbonate of ammonia. If pure, the bread is only stained pink; if alum be present, a marked blue to violet colour is produced. The estimation of the precise amount of alum in bread involves a somewhat lengthy process which is beyond the scope of this book. Although bread differs somewhat in composition from flour, its disadvantages as a food are more or less the same, namely, too little fat and too little sodium chloride or salt. In daily life, the deficiency of fat is made up by eating butter, dripping, or bacon with bread, while in the baking half an ounce of salt is added for each 4 lbs. of dough.

A variety of fancy and patent breads are in the market. The various kinds of Vienna bread are good examples of the former class. These are made from fine flour, milk being added to the dough, and fermentation secured by compressed yeast. Of the patent breads, most are brown in colour, and are made from flours prepared by patent processes. Hovis bread is a well-known example; this is made from flour containing considerable amounts of the "germ" of wheat. The germ is a part of the wheat grain rich in fat and protein. In the milling of ordinary flour the germ is discarded as offal. Being made from flour which contains some of the most highly nutritive parts of the wheat, Hovis bread naturally possesses an enhanced nutritive value. Some other breads are malted. In their preparation malt extract, which contains the ferment diastase, is added to the dough at any early stage before baking. The diastase converts the starch of the dough into malt sugar and dextrin, or, in other words, more or less digests it. Such bread tends to keep moist. Bermaline bread, made by Montgomerie's process, belongs to this group. The diastatic ferment

is, of course, killed or rendered inactive during actual baking. A recent agitation for what is called "standard bread" is but an expression or protest against the removal from flours of the germ and other highly nutritive parts of the original or natural flour. To a large extent the demand for a standard bread is misdirected, as there are wide differences in protein content and energy value between different wheats. Thus entire wheat flours, including stone ground and standard flour, when made from weak flours, contain less protein and energy value than "households," which have been made from strong wheat. The practical remedy appears to be to increase the quantity of bread taken rather than to rely upon the substitution of one special form of bread for another, and in the case of children to supplement the presumably low-grade bread by other articles, such as milk.

Biscuits.—The ordinary kinds are nothing more than well-baked mixtures of flour and water, though the more fancy varieties contain often milk, butter, and eggs. Owing to the absence of yeast in their preparation, biscuits do not contain the products of its action upon the carbohydrates and proteins of flour. Taking weight for weight, biscuits contain more nourishment than bread, but are apt to be indigestible and monotonous if consumed for long.

Macaroni and Vermicelli.—These are both preparations of flour. They are made chiefly from the flours of the hard wheats of France and Italy, which are particularly rich in glutin. They are very valuable foods, being distinctly of higher nutritive value than bread.

Barley very closely resembles wheat in its composition, but differs somewhat in the character of its proteins. These do not on the action of water form glutin, but remain in a soluble form as globulin, albumin, and albumose. It is difficult to say how far this affects its nutritive value, but it undoubtedly affects the capability of barley being made into bread, and as such largely used as an article of diet. Its starch grains resemble both in size and appearance those of wheat, but their rings or markings are more distinct. When the whole barley grain is ground, it forms *barley-meal;* when deprived of its husk, and roughly ground, it constitutes *Scotch*, *milled*, or *pot barley*.

Pearl barley is the grain deprived of the husk, rounded and polished by rubbing. So-called *patent barley* is merely pearl barley crushed to the state of flour. Barley water is prepared from pearl barley, and forms a slightly nutritive liquid for infants and the sick. *Malt* is the product yielded when barley has been allowed to germinate, and the germination stopped at a certain point by

exposure to heat on a kiln. As a result of this process, the starch of the grain is largely converted into sugar by the development within the barley grain of a peculiar active nitrogenous ferment called diastase. It is from malt that beer is largely made. There being little or no glutin in barley, it cannot be made into ordinary bread; when barley bread is made, it is usually from a mixture of barley-meal with wheaten flour. Barley cakes are eaten in some places on the score of economy; but, as compared with those made from wheat, are less palatable and less digestible.

Rye.—Although little used in this country except for malting, rye in the northern countries of Europe is largely used for making bread. In its percentage composition, rye closely resembles wheat, its proteins forming, on the addition of water, a kind of glutin. Rye bread is dark in colour, somewhat heavy and very acid; but falling little short of wheaten bread in nutritive value. Rye bread is indigestible and apt to cause diarrhœa. If mixed with two parts of wheat-flour, rye-flour makes an excellent bread. The starch grains of rye are very like those of wheat or barley; but, however, have usually a hilum which is star-shaped, while some of the grains are very large in size (Fig. 18). The common rye is a very hardy cereal, and is commonly sown in soils which are too poor to grow wheat. Rye is subject to a very peculiar fungus disease, by which the grain is enlarged and turned black, producing what is known as ergot of rye. The cause of the disease is a fungus called the *Claviceps purpurea*. When the ergot gets mixed with healthy rye, it becomes mingled with the bread, and leads to a disease in men called ergotism, the symptoms of which are vomiting, diarrhœa, followed in severe cases by either loss of sensibility, gangrene, or paralysis. This disease is practically unknown in this country, and much less prevalent now than formerly abroad. On account of the excessive size which ergotized rye grains attain, they can be separated by sifting from the unaffected seed: when the grain has been ground into flour, the ergot may be detected either by the microscope or by making of it a paste with an alkali, and then adding nitric acid to excess; on neutralizing, if ergot be present, a violet-red colour is produced.

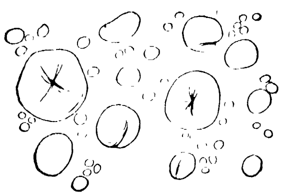

FIG. 18.—Rye starch.

Oats.—As met with in commerce, oats consist of the seeds of the *Avena sativa* enclosed in their husks. When deprived of this integument, the grain goes by the name of *groats*, or *grits*, used in making porridge; and these groats, when ground down fine,

constitute *oatmeal*, from which gruel is made. Of all the cereals, oats rank next to wheat as articles of food, being noticeable for containing large amounts of portein and fat — particularly the latter. Oats resemble barley rather than wheat, in that their proteins do not form glutin on the addition of water; on this account oatmeal cannot be vesiculated and made into bread like wheaten flour. It is, however, made into thin cakes by mixing into a paste with water, and then baking on an iron plate. Owing to the large amount of cellulose which they contain, this is apt to irritate the intestines, and more or less interfere with digestion. The grains of oat starch (Fig. 19) are minute and faceted, often tending to collect together into groups or compound grains. In the form of oatmeal, oats can be taken for long periods without distaste, and in this form constitute a material part of the dietary of the Scotch peasantry.

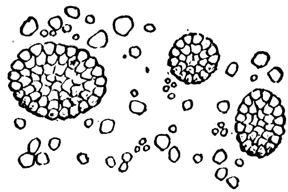

FIG. 19.—Oat starch.

Rice.—The common rice, or *Oryza sativa*, is extensively cultivated in India, China, West Indies, Central America, and in some parts of Southern Europe. Its starch grains (Fig. 20) very closely resemble those of oats. Rice is a peculiar grain food, inasmuch as it is remarkably poor and deficient in proteins, fats, and salts. For this reason it needs to be combined with meat, peas, or beans, to supply the protein with fat, and common salt. It is essentially a carbohydrate food, and, if properly and sufficiently cooked, is very digestible. It is best cooked by thoroughly steaming; if boiled in water, it loses some of its already small quantity of protein and saline matter. It cannot be made into bread, but is much used in France for mixing with wheaten flour to make the very white bread which is in request in that country. Among large rice-consumers a diseased condition, known as beri-beri, results from the consumption of an over decorticated rice. This successive removal of the outer coverings of the rice grains removes the vitamine containing cells, and proportionately lessens the nutritive value of the rice.

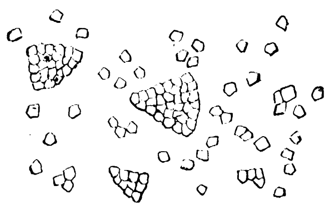

FIG. 20.—Rice starch.

Maize.—Though not much used in England, maize, or Indian corn, is an important food in America and in Italy, where it is

called *polenta*. In its nutritive value, maize resembles oats, containing a large quantity of fat. When made either into cakes or porridge, it affords a valuable food. Maize, being deficient in glutin, does not make good bread; it is, moreover, harsh in flavour. This defect is largely removed by treating it with caustic potash, a procedure which is the foundation of the process for making it into the common commercial articles extensively sold under the names of oswego, cornflour, and hominy. If imperfectly cooked, or at all decomposed, maize may give rise to very disturbing symptoms. The grain, too, is liable to a peculiar disease due to a fungus called *Sporisorium maidis*, which gives rise to a disease in man known as "pellagra," and closely resembling scurvy. This affection is not uncommon in Lombardy, where much maize is eaten as food. The starch grains of oats, rice, and maize somewhat resemble each other, in being all of them faceted. The maize starch grains (Fig. 21) are much larger than the other two, with a distinct hilum; oat and rice starch grains are smaller than those of maize, and are usually without a hilum, while both the oat and rice grains have a tendency to collect together into clumps.

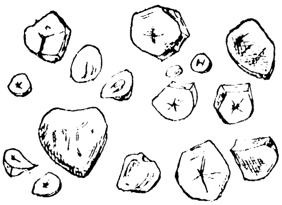

FIG. 21.—Maize.

Peas and Beans.—These belong to the leguminous group of seeds, which also includes lentils. They have a high dietetic value, in consequence of the large amount of protein which they contain; this is called *legumin*, or vegetable casein, and exists largely in combination with sulphur and phosphorus. Both peas and beans are less digestible than the cereals, and require to be boiled slowly for a long time. Added to rice, foods of this class largely furnish the nitrogenous material in the diets of the natives of Hindustan; but to those unaccustomed to such, it is doubtful whether leguminous seeds can replace the animal proteins. Their large amount of contained protein adapts them for consumption in association with starchy and fatty articles; a familiar example in our own country being beans and bacon. Unfortunately they are difficult of digestion. The starch grains of peas and beans (Fig. 22) are characteristic, being oval or kidney-shaped; they have no clear hilum, but usually a deep

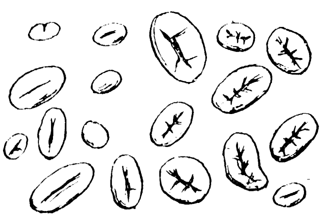

FIG. 22.—Pea flour.

central longitudinal cleft, or at times an irregularly shaped depression. The addition of hot water to pea or bean flour causes the emission of the typical beany smell. Closely allied to the foregoing foods are the potato, the various arrowroots, sago, and tapioca.

Potatoes.—These may be considered as occupying a place next in importance to the seeds of the cereals as articles of vegetable food. The potato, used as food, constitutes the tuber or exuberant growth of a portion of the underground stem of the *Solanum tuberosum.* The tuber develops into a thick fleshy mass, retaining its buds under the name of "eyes," each of which eyes or buds is capable of independent growth when in a detached or isolated state. In its chemical composition, the potato shows a large proportion of starch with a very small quantity of protein. The juice of the potato is acid, due to the presence of a certain amount of free citric acid with citrates of potassium, sodium, and calcium. In its dietetic value the potato is both a carbohydrate and an antiscorbutic. The starch grains of the potato (Fig. 23) are characterized by being large oyster-shaped granules with well-marked concentric rings, and a clear though small hilum at the narrow end. Potato starch is largely used for adulterating the more expensive farinaceous dietetic preparations; though cheaper, there is nothing to show that potato starch is less nutritive than other starches. Potatoes require to be cooked before being eaten; this may be done by either steaming, boiling, baking, or frying. The heat coagulates the albuminous juices, and the absorbed water swells up and distends the starch grains. When these changes are complete, the potato is said to be mealy or floury; when these changes are only partially completed, and the starch cells imperfectly broken up and separated, the potato remains more or less firm, and is spoken of as being close, waxy, or watery. The potato plant is sometimes affected with a fungus—the *Phytophera infestans*—which causes the disease known as potato murrain. This can be readily detected by the microscope. The disease commences in the leaves of the plant, and thence extends to the stem and on to the tubers. On the surface of the latter, brown spots make their appearance, penetrate the potato, and eventually cause it to rot and decay.

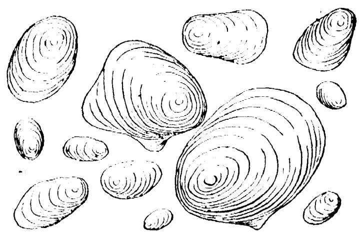

FIG. 23.—Potato starch.

Arrowroots.—The arrowroots are obtained from various

sources. Originally the term arrowroot was applied to the starch from the tuber or rhizome of the *Maranta arundinaceæ*, because that root was supposed to have the power of counteracting the effects of poisoned arrows. The term is now applied to a great variety of starches, but, strictly speaking, should be limited to those known in commerce as Canna, Curcuma, Maranta, and Tacca arrowroots. The root of the plants are dug up when about a year old, washed, and reduced to a pulp. This is repeatedly washed, passed through coarse sieves to separate the fibres, and the starch allowed to settle, which again is washed and dried. When finished ready for exportation, arrowroot is a white, tasteless, odourless substance, firm to the feel, and producing, on pressure, a slight crackling noise. Arrowroot, being a pure starch, has no dietetic value beyond that peculiar to this substance. It is chiefly used as a bland article of food for invalids, or, in an ordinary way, as blancmange, puddings, and biscuits.

Canna arrowroot is furnished by the *Canna edulis*, a native of the West Indies. Its starch grains are very like potato, but, on the whole, are larger and flatter with more definite striæ, or markings.

Maranta arrowroot, sometimes spoken of as Bermuda arrowroot (Fig. 24), is derived from the *Maranta arundinaceæ*, a plant which grows in Jamaica and Bermuda. Its granules are long and ovoid; the rings, or striæ, are well-defined; while the hilum is in some circular, and in others a mere transverse line or slit.

Curcuma arrowroot is furnished from the *Curcuma angustifolia*, a species of turmeric plant. Its starch grains vary much in size, being, as a rule, flat and elongated. The striæ are not complete circles, and the hila, if present at all, are at the narrow end of the grain.

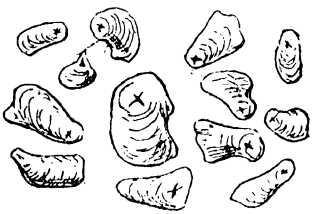

FIG. 24.—Arrowroot starch.

Tacca arrowroot is obtained from the *Tacca oceanica*, growing in Tahiti. Its granules are truncated, or wedge-shaped at one end. Their striation is indistinct, with a more or less circular hilum. All these starches of arrowroots readily form clear jellies on cooling after being heated with water. The true arrowroots are chiefly adulterated with potato, sago, and tapioca. What is called English arrowroot is merely potato starch.

Tapioca is a starch (Fig. 25) in the form of small granules, truncated at one end with large bases, indistinctly ringed, and with

a more or less star-shaped hilum at the apex. It is prepared from the roots of the *Jatropha manihot*, or *Cassava*, growing in the Brazils.

FIG. 25.—Tapioca starch.

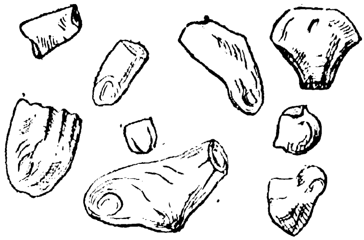

FIG. 26.—Sago starch.

Sago is another starch (Fig. 26) obtained from the interior of the *Sagus farinifera*, or sago palm, growing in Sumatra. The starch grains are very similar to those of tapioca, but larger.

Among the large class of succulent vegetables are such common articles of everyday life as cabbage, carrots, parsnips, turnips, beetroot, lettuce, etc. These can scarcely be regarded as foods, because the greater part of their carbohydrates exists in the indigestible form of cellulose, while their contained water amounts to about 90 per cent. Their general percentage composition may be put as—protein, 2; fat, 0·5; carbohydrate, 7; salts, 1; water, 89·5. All these vegetable foods are valuable for their antiscorbutic properties and for the salts which they contain, their absence from a diet leads to the production of scurvy.

The fruits are chiefly esteemed for their taste, though being, as they are, rich in water, vegetable acids, and salts, they are distinctly of service as preventatives of scurvy. Some fruits, such as grapes, contain sugar; while others, like dates and bananas, contain not only sugar, but starch. When eaten, fruit should not only be ripe, but quite free from decomposition. Some few, like dates and figs, can be dried, but the softer and more perishable varieties cannot be too fresh when eaten.

Limes and Lemons.—There is a strong traditional belief in the efficacy of the juices of these fruits as preventatives of scurvy. This is justified so long as it is the juice of the *Citrus medica limonum*, or sweet lime, which is used. Its value in the navy and mercantile marine was demonstrated overwhelmingly up to about 1880. Subsequent to that date many outbreaks of scurvy among crews of ships have occurred notwithstanding the issue to them of lime-juice. The explanation is that, prior to that date, lime-juice had been made exclusively from the *Citrus medica limonum*, which grows in Italy, Sicily, and other countries in the Mediterranean

basin. Subsequently, the bulk of the lime juice issued to crews was made from the *Citrus medica acida*, or sour lime, from Montserrat in the West Indies. The juice of this variety has very little anti-scorbutic value, or only one-fourth of that of the Mediterranean sweet lime. Hence the occurrence of scurvy among crews in spite of an issue of lime juice, and the necessity to recognize that there is a spurious as well as a genuine variety. In the absence of fresh food, especially fresh meat and vegetables, one fluid ounce of the juice of the sweet lime from the Mediterranean is an effective daily issue for the prevention of scurvy.

Both lemon- and lime-juice contain large quantities of citric acid with some malic acid, protein, and sugar. The citric acid, which is an important constituent, averages from 7 to 8 per cent. Apart from their value as anti-scorbutics, both lime- and lemon-juice furnish agreeable and refreshing beverages; they allay thirst and sickness, and are of special value, too, as antidotes in poisoning by the alkalies. A good and pure lemon-juice should be clear, with an acid but not bitter taste, and possessed of a distinct aroma of the fruit. Many substitutes for lemon-juice are sold, the chief being a solution of citric acid in water flavoured with essence or oil of lemon. The chief adulterations are watering, and the additions of sulphuric and tartaric acids. The addition of water can be detected by the lowering of the specific gravity below 1030, and the diminution of the acidity below 30 grs. of citric acid per ounce. Sulphuric acid is probably the most important adulteration; it may be detected by filtering, and, after acidulation by hydrochloric acid, treating with chloride of barium, when the insoluble barium sulphate is thrown down, if sulphuric acid be present.

Preserved Foods.—For the preservation of meat, the chief methods are drying, freezing, salting, the injection of preservative solutions, and the exclusion of air, whether by covering it with an impervious coating or by hermetically sealing in tins. Meat preserved by *drying* is first cut into thin slices, and then exposed to dry air, or to the smoke from a wood fire. In some countries, exposure to a hot sun is sufficient. The employment of extreme cold by *freezing* is now a very common mode of preserving meat, especially during importation from America and Australia. Meat can be preserved in ice for a long time, but unless the freezing had been commenced before rigor mortis set in, such preserved meat rapidly decomposes so soon as thawing is allowed. Experience shows that it is better to keep the meat at a temperature just short of freezing—say, 35° F. The excellence of the refrigerated meat now available is evidence of the success of this manner of preserving the flesh of animals.

Pickling by means of *salting* is an old and familiar means of preserving meat. During the process, the water of the meat is abstracted, and the salt acts as a preservative. Closely allied to this method is that of *injecting preservative solutions*, such as alum, or even common salt, and also by the application of preservatives to the surface, notably salt, sugar, boracic acid, salicylic acid, and charcoal. The *exclusion of air* is either secured by coating the meat with paraffin, or simply fat, and even by the simple device of plunging the joint into boiling water, so as to form an impervious layer of coagulated albumin on the surface. Probably the most frequent method based on air exclusion is that of hermetically sealing in tin cases. Various devices for securing this have been suggested, the chief being either a complete exclusion of the air by sealing *in vacuo*, or the exclusion of only a part of the air and removal of the oxygen of the remainder by sodium sulphite.

The chief objections to all these methods are, first, the danger depending upon possible original defects in the meat, and, secondly, the risks of decomposition and putrefaction if the preservation have been imperfectly carried out. In the case of tinned meats, not infrequently ill effects have followed their consumption, even when the original material has been above suspicion, and no sign of putrefaction has been present in the tin contents; the only unusual character being the presence of salts of tin, lead, or zinc in the meat and jelly, due possibly to the action of variable organic acids upon the solder or tin. Fortunately such events are rare. In the case of tinned or preserved peas an objectionable practice prevails of adding copper salts to give a green colour to the article. A special Committee appointed under the Sale of Foods and Drugs Act has reported that the use of copper salts in the so-called greening of preserved foods be prohibited.

As being closely allied to preserved forms of meat, allusion may here be made to the many *extracts of meat* now in the market. Some of them are pure stimulants, and not foods, while others are both. Among the former are Liebig's Extract, ordinary beef-tea, and the soups. These are not protein foods, for besides gelatine they contain only the merest traces of any other protein; most of the myosin is coagulated during preparation, and left behind in the solid residue. These extracts are really salty foods, containing the sodium chloride from the blood and muscle liquid, the phosphates and potash from the muscle fibre itself, along with the extractives, such as kreatinin. They are essentially stimulants, restoring both mental and bodily activity, but in no sense can be regarded as true nitrogenous foods. On the other hand,

there are some preparations which, besides being stimulants, are also protein foods. These are made by drying more or less completely, partially digested meat, and then mixing with this glutin, starch, and concentrated milk. To this class belong such preparations, often given to invalids, as Bovril, Beef Peptonoids, Fluid Meat, and others. It is of importance to understand the true value of these preparations, as too often their use is misapplied, owing to a misconception of their real nature.

The yeast extracts cannot be regarded as substitutes for meat extracts. It is true the yeast extracts are rich in albuminous bodies, but these nitrogen containing substances are nearly all nucleo-proteins, or what are called "purin bases." True meat extract contains creatin and creatinin to the extent of 10 per cent.; yeast extracts contain practically neither of these substances. Apart from the purin bases of meat extract being much less than those present in yeast extract, there is a wide divergence between the two as to the representative purin bases which they contain; meat extract is rich in hypoxanthin with a little xanthin, while yeast extract contains chiefly adenin and guanin with very little hypoxanthin. Owing to their richness in these particular purin bases, yeast extracts are most unsuitable for the gouty; in any case they must be regarded as not the equivalent for true meat extracts.

The dietetic position of condensed and dried preparations of milk has been considered in the section devoted to that food.

Food Accessories.—This term has been proposed for the great group of condiments and beverages, because they include food stuffs which, though not absolutely necessary for existence, are still of much importance as aids to digestion and to the relishing of the more ordinary articles of diet. The Germans call them "means of enjoyment," as distinguished from the true foods or "means of nourishment." They include substances varying from the simplest aromatic principles, such as one smells when meat is cooking, or condiments and spices, to the more complex alcoholic and non-alcoholic drinks which so largely enter into the daily dietaries of both civilized and uncivilized peoples. The general action of the food accessories seems to be to stimulate digestion, either directly by affecting the digestive organs, or indirectly through the central nervous system. The condiments are mainly added to food as flavouring agents; they include such articles as mustard, pepper, onions, cloves, nutmeg, cinnamon, salt, and vinegar. Excepting the two last, all these owe their value as food accessories to aromatic oils which they contain. These essential oils are all stimulants directly of the muscular movements of the digestive organs and of the secretion of their juices;

but if taken in excess, easily induce gastric catarrh and exhaustion of the mucous lining of the stomach. The influence of common salt has already been discussed.

Vinegar is dilute acetic acid, more or less contaminated with gum, sugar, vegetable matter, etc. The varieties of vinegar met with in the market are wine vinegar, malt vinegar, and wood vinegar. The first two are produced by fermentation of alcohol, the process being one of oxidation from alcohol into aldehyde and then into acetic acid; the last by the destructive distillation of wood and subsequent separation of the acetic acid. The percentage of acetic acid ought not to be below 3 per cent., while in the best vinegars it may be as high as 6 per cent. Its specific gravity, if a wine vinegar, varies from 1015 to 1022; if a malt vinegar, from 1016 to 1019: anything below these figures is suggestive of dilution with water. The chief adulteration of vinegar is the addition of sulphuric acid in excess of that permitted by law, namely, 1 in 1000. If an excess be suspected, it must be determined by barium chloride. Occasionally, artificial vinegars are sold, being really nothing more than very dilute acetic acid coloured with caramel; they lack, however, the odour and bouquet of the volatile ethers which are so characteristic of the alcoholic fermentation products. The use of vinegar is not only that of an aid to food relishment, but, like other vegetable acids, helps to maintain the alkalinity of the blood, by conversion of the acetic acid into carbonates within the body. In doses of from half to an ounce daily, vinegar is an antiscorbutic, though inferior to lime- and lemon-juice. It is also an aid to digestion, particularly of some shell-fish, such as oysters and mussels. If taken in excess, especially when adulterated with sulphuric acid, vinegar tends to impair digestion.

The beverages included among food accessories may be divided into those which contain no alcohol and those which do. The non-alcoholic beverages owe their action as food accessories chiefly to the alkaloids they contain; the more common of these beverages are tea, coffee, and cocoa; the two former have as their active principle the alkaloid theine or caffeine, while cocoa contains theobromine. Theine or caffeine is essentially a brain stimulant, exciting it to continued activity. If taken in excess, it produces not only an exhausted and disordered nervous system, but gives rise to acid dyspepsia, and considerable delay in the digestive process. Theobromine, though closely allied in its chemical nature to caffeine, has a slightly different physiological action, exerting its effects rather upon the muscular system, which it stimulates into activity, than upon the nervous system.

Tea consists of the dried leaves of a shrub called the *Camellia*

thea, which grows in China, India, Ceylon, and Japan. As met with in everyday life, tea-leaves are curled, but they uncurl on being placed in hot water, and when so treated, are found to be ovate in shape, pointed, and with a margin toothed like a saw almost to the stalk. The arrangement of the veins in the tea-leaf is characteristic; the large veins do not reach to the border of the leaf, but turn in towards the midrib. The size of the leaves varies, and usually with them is some stalk. Practically all tea in the market is grown from the same species of shrub, the various names given as indicating different kinds are only trade names, and do not indicate really different varieties of tea-leaf so much as different qualities dependent upon mixing or blending, and on the age of the leaves, or on the soil on which the plant has been grown. In all cases, the leaf most highly valued is the small top leaf of the twig and the bud. Possibly these small leaves are neither finer in quality nor richer and better in flavour than the leaves next in succession, but being more tender and softer in structure, give better and more flavoured infusions. The various teas known under a variety of trade names are all the same in respect of origin, being picked at the same time from the same shrub. Thus, the bud and top leaf constitute Orange Pekoe, the two or three larger leaves growing on the same twig a little lower down are Suchong, and below that the leaves become Congou.

The most simple division of teas is into the green and the black; both are from the same plant, the only difference is their colour. Green tea is now little used, in consequence of the disrepute into which it fell as the result of the artificial colouring it received; but real green tea owes its colouration to being dried over wood fires when fresh. Black teas owe their colour to the leaves having been allowed to lie in heaps for twelve hours, during which they undergo a process of fermentation, and are afterwards dried slowly over charcoal fires. "Brick tea" is made from the refuse, broken leaves and twigs, moulded into shapes. In selecting a fine tea, one should not be guided by any trade name, but determine by pouring a little boiling water over the leaves and examining them, whether the leaf was a whole leaf and not a large leaf cut into small pieces. The larger the leaf, the weaker will be the infusion and the less the value. What are called "digestive" teas are varieties in which the tannin of the tea has been so altered by electrical treatment that it does not precipitate gelatin, and interferes but little with the digestion of starch.

The average percentage composition of tea may be expressed as follows:—

Water	8·0	
Theine	2·6	
Tannin	14·0	
Oil	0·4	
Extractives	15·0	
Insoluble organic matter	54·0	
Ash	6·0	Potash, iron, silica, alumina, magnesia.

Formerly, the chief adulteration of tea was by mixing with it other leaves, such as those of the sloe and willow, which have a superficial resemblance to tea-leaves. At the present time the chief adulteration of tea is the admixture of old and exhausted tea-leaves, while in the inferior kinds there is often clay, lime, or ferruginous sand. The total soluble matters obtainable from tea are a ready and convenient index of its quality: they are estimated by infusing a weighed quantity with an excess of distilled water, and evaporating this down to dryness; the amount of extract so obtained should be at least 30 per cent. If the sample contain many exhausted leaves, the amount of extract obtained will be, of course, less than this. The ash obtained by burning a given quantity of the tea sample should, in a good specimen, be at least 5 to 6 per cent., and not more than 8 per cent.; and of this at least 3 per cent. or half should be soluble. The precise estimation of the theine and tannin are matters of some difficulty, but are not certain data upon which to judge the purity of any particular sample.

The most essential points in making good tea of the finest quality and with the least waste are to have actually boiling water, and tea-leaves so crushed and subdivided that the largest possible surface is rapidly exposed to the boiling water in infusing it. This explains why the best tea-infusion in the world is that made by the Japanese from their carefully prepared "tea-powder," which is made by crushing to a fine powder certain well-selected leaves. The tea bricks of China probably owe their superiority to being well-crushed leaves of good quality. The use of tea-powder obtainable in Europe, is handicapped by its liability to adulteration, its uncertain mixture, and difficulties in its preparation. Possibly these disadvantages may be overcome by a more extended employment of tea tabloids, made by the compression of carefully selected and finely ground teas from Japan, India, and Ceylon.

The excessive drinking of tea is bad, especially when fasting. Tea is not a food, and should not be taken as such; but if used in moderation, it undoubtedly serves a useful purpose among our daily wants. It is essentially a stimulant of the brain and nervous system, producing no subsequent depression; but if taken in

excess induces indigestion, loss of appetite, and constipation: in some persons, these bad effects are produced even when only small quantities are consumed. Indian teas are richer in astringent properties than the China teas, for this reason the latter are less disturbing of digestion.

Coffee is the seed, or berry, of the *Caffea Arabica*, a plant growing in most parts of the tropics, but chiefly in Arabia, Abyssinia, Ceylon, and the West Indies. After the seeds have been roasted to a chocolate brown, they are ground to a powder in a mill, and then used in the form of a decoction or infusion. The percentage composition of unroasted coffee may be expressed as follows:—

Water	11·23
Nitrogenous matter	12·07
Caffeine	1·21
Fat	12·27
Sugar or dextrin	8·55
Tannin	32·79
Cellulose	18·17
Salts	3·71

The chief properties of coffee depend upon an aromatic oil and an alkaloidal body called caffeine. Caffeine itself is a nitrogenous crystalline alkaloid identical with theine; in the roasting of coffee this body is not destroyed, but dissociated, as it were, from its previously existing combination with tannin. During the same process the sugar and dextrin are changed into caramel, and the gas and water of the berry are driven off.

The adulterations of coffee are chiefly chicory, but at times dates, beans, maize, and acorns have been added. Chicory is a legal addition to coffee, provided such admixture be stated, no limit being fixed as to their relative proportions; as a rule, it amounts to about 30 per cent. The addition of chicory to coffee is considered by most people to add to its flavour. It is probable that much of the present decadence of coffee drinking is due to the excessive addition of chicory, whereby the resulting infusion is wanting in the desired alkaloid caffeine. To make good coffee the berry must be freshly roasted. Good drinkable coffee requires as much as an ounce of recently roasted and ground coffee to each large cup. The prevalent custom in this country is to use barely an ounce to two pints of water, the resulting infusion being more or less mawkish, tasteless, and wanting in stimulating properties. Chicory itself is the dried and powdered root of a plant called the *Cichorium intybus*. In composition it differs much from coffee, containing no caffeine, less fat, but more sugar. It may be readily distinguished from coffee by the fact that when

thrown into water it rapidly sinks and colours the liquid brown, while coffee floats and does not yield any colour. If adulterations are present in the form of the starch grains from various cereals, both a microscopical examination and the blue reaction with a dilute solution of iodine will betray them.

A more exact estimation of chicory in mixtures of coffee and chicory can be made by calculating the percentage of extract yielded by the sample after infusion in boiling water. Pure chicory gives a mean percentage extract of 70; while pure coffee gives a remarkably constant percentage extract of 24.

Coffee, like tea, appears to act decidedly upon the nervous system, which it stimulates, causing wakefulness and increased brain action. In some people it has an aperient action by stimulating the muscular coats of the intestines.

Cocoa is the roasted seed of the *Theobroma cacao*, growing chiefly in the West Indies. Cocoa nibs are the seeds or beans roughly broken; flake cocoa is the same completely ground and crushed; soluble cocoa is the same freed from cellulose; while prepared cocoa is the same after half or more of its contained oil or fat has been removed, and in most cases starch and sugar added. The percentage composition of cocoa beans may be said to be as follows:—

Water	6·0
Theobromine	1·5
Fat	50·0
Starch	10·0
Salts	3·6
Gum	8·0
Cellulose	20·9

Theobromine closely resembles caffeine, not only in its nature, but in its action. The adulteration of cocoa is chiefly in the direction of the addition of sugar and starch, which the microscope will detect; while, by some, the removal of the fat, so as to reduce it below 20 per cent., is regarded as an adulteration. Apart from cocoa by nature containing nitrogenous and fatty matter, in its commercial forms it contains so much starch and sugar that it is rightly regarded to some extent not only as a protein and fatty food, but also a carbohydrate one. Cocoa differs much from both tea and coffee in having but little stimulant action, but it does possess some nutritive value, and, as such, may in a limited sense be regarded as a food.

Chocolate is a preparation of cocoa, from which the greater part of the fat has been removed, and which, after being mixed with sugar and various flavouring substances, is made into a paste with water, and then pressed in moulds.

Aerated Waters.—In addition to the large number of natural waters, rich in carbon dioxide, there are many artificial aerated waters which have come into general use of late years. The peculiar feature of them all is that they are prepared by forcing carbon dioxide into ordinary water, and adding to it either some saline or a flavouring agent. Much of what is known and largely sold as "soda water" really contains no soda at all, but is merely an ordinary water highly aerated and charged with carbon dioxide. If the gas, naturally present in the water, is not previously thoroughly expelled, the carbon dioxide is imperfectly dissolved, and when the bottle is opened, tends to froth and escape violently. The chief sources of danger in these beverages lie in the possible employment of originally impure water; the making of the carbon dioxide from impure materials; the presence of either lead, copper, or tin, as the result of imperfect washing of the gas, or derived from the plant used in the manufacture. These dangers can only be obviated by the exercise of care in the selection of the water and materials used. Fortunately carbon dioxide, under pressure, is antagonistic to the majority of micro-organisms present in water. This is a fact which may in great measure explain the remarkable immunity from filth diseases, such as enteric fever and cholera, which attends the habitual use of highly aerated waters in place of the ordinary supplies. It would, however, be desirable if legislation could make it illegal to use any water but that possessing all the qualities of an unobjectionable drinking water for the making of aerated beverages. The presence of any deleterious metals is uncommon in these drinks, except those made in inferior and faulty machines. The aerated waters stored in bottles with patent stoppers of porcelain, glass, and vulcanite are, of course, the most generally free from any of the hurtful metals. It is questionable whether any real danger exists to health under this heading.

Alcoholic Beverages.—Among the alcoholic beverages, the chief are beer, wine, and spirits; these all owe their action as food accessories partly to the alcohol and partly to certain aromatic principles and substances which they contain. The alcoholic beverages are sometimes called fermented liquors, because the alcohol contained in them is the result of a process called fermentation set up in either the natural sugars which we extract from fruits, stalks, or roots of certain plants, such as the grape, the sugar-cane, and the beetroot, or in the secondary sugars which we prepare by art from potatoes, cereal grains, malt, and the starches generally.

If we take a natural sugar, such as grape-sugar present in the fruit of the vine, dissolve it in water, and add a little yeast to it,

the solution quickly begins to ferment. During this fermentation the sugar is split up into alcohol and carbon dioxide. The former remains in the liquid, while the carbon dioxide escapes as a gas in bubbles into the air. The yeast which brings about this remarkable change is in reality a microscopical plant, made up of oval cells about $\frac{1}{2000}$ of an inch in diameter, filled with granular matter. The scientific name for yeast is *Torula cerevisiæ*. It is by virtue of this fermentation of grape juice, as we shall learn later, that wine and brandy are made. If instead of grape-sugar, we take common cane-sugar, dissolve it in water, and mix with yeast, fermentation is set up in a similar way; excepting that the cane-sugar is first changed into fruit or grape-sugar by the action of the yeast, and then the grape-sugar is split up into alcohol and carbon dioxide. These changes go on whether the sugar be exposed to the air or not. If now, instead of taking either grape-sugar or cane-sugar, we take some ordinary starch, boil it in a dilute solution of almost any acid, particularly 1 per cent. of sulphuric acid, the starch is converted into a sweet gum-like body called dextrin, and subsequently into a kind of sugar called maltose, which closely resembles in sweetness, chemical composition, and general properties that of the grape. If yeast be now added to this altered starch, the same fermentation and production of alcohol takes place. It is from potato starch treated in this manner that large quantities of spirit, known as potato brandy, are manufactured in various countries.

In a previous chapter it has been explained that the cereal grains consist essentially of two principal substances—namely, starch and a nitrogenous body of the nature of a globulin or albumose. These evidently are intended by nature to afford the first food of the young plant as it grows from the grain; but in their natural state these are insufficiently soluble to supply the wants of the growing germ. Under the influence of moisture, as when a grain of wheat sprouts, a ferment in the form of a soluble white substance called *diastase* is formed in the grain, which so converts the nitrogenous elements of the seed as to make it usable by the young plant, and for the same purpose also changes the insoluble starch into soluble starch, dextrin, maltose, and glucose or grape-sugar. This is why sprouted corn always has a sweet taste. The maltster, brewer, and distiller avail themselves of this natural change in the constituents of sprouting grain, and on a large scale call into action the chemical influence of this unorganized ferment known as diastase.

In the manufacture of all fermented drinks, therefore, two distinct chemical processes are involved; there is first the change of the starch into sugar, and secondly the change of the sugar

into alcohol and carbon dioxide. This latter we know is brought about by fermentation through the medium of yeast, while the former may be secured by the artificial conversion, by means of sulphuric or other acid, of potato or other starch into sugar; or the grain may be manufactured into malt and the remarkable influence of diastase called into play.

The essential element in all fermented drinks, no matter how made, is alcohol, which is a neutral compound of oxygen, carbon, and hydrogen, having the chemical formula of C_2H_6O. When quite pure and free from water, alcohol is termed *absolute alcohol*, having a specific gravity at 60° F. of 0·79381; when mixed with 16 per cent. of water, it is called *rectified spirit*, and when mixed with 56·8 per cent., volume in volume of water, it constitutes *proof spirit*. Proof spirit is a term constantly in use for excise purposes, signifying a dilute spirit of definite strength. If expressed as volume in volume, proof spirit contains 56·8 per cent. of absolute alcohol; if as weight in weight, 49·25 per cent.; if as weight in volume, 45·4 per cent.; the remainder in each case being distilled water. The ratio of alcohol to proof spirit in each of these cases being for volume in volume as 1 is to 1·76; for weight in weight as 1 is to 2·03, and for weight in volume as 1 is to 2·21. We can, therefore, if in any case the percentage of contained alcohol be known, calculate the amount of proof spirit present by multiplying the given percentage of alcohol by any of the foregoing ratios.

Spirits which are weaker than proof are described as being *under proof;* when stronger than proof as being *over proof*. Thus, say a sample of whisky is found to contain 70 per cent., volume in volume, of alcohol; then $70 \times 1·76 = 123·2$, and the excess of this product over 100 or 23·2 gives the number of degrees over proof which the sample has. If, on the other hand, it contain but 24 per cent. of alcohol, volume in volume, then $24 \times 1·76 = 42·24$, and by just so much as this figure is greater or less than 100 is the sample degrees over or under proof, that being, in this case, just 57·76° under proof. Conversely, if the degree of strength of any spirit over or under proof be known, the percentage of alcohol present can be calculated either as volume in volume, weight in weight, or weight in volume. Thus, say a sample of brandy be x degrees over proof; then $\frac{100 + x}{1·76}$ gives the percentage, volume in volume, of alcohol which it contains. If it be x degrees under proof, then $\frac{100 - x}{1·76}$ gives the percentage, volume in volume, again of alcohol.

Nutritive Use of Alcohol.—The use of alcohol by man is of

very ancient origin, and owing to the ease with which alcohol is produced by fermentation from sugars and starches, its early discovery and almost universal use throughout the world are not at all remarkable. In attempting to understand the physiological action of alcohol, one must bear in mind that there is a distinction between the effects of alcohol taken in dietetic doses and when taken in excess, and too, that the physiological action of pure alcohol is not quite the same as that of many alcoholic beverages, because many of these contain other bodies besides alcohol, and which have a distinct action of their own. Moreover, it must not be forgotten that what is a dietetic dose for one person is an excess for another. As based upon the experiments of Parkes, Anstie, and others, the amount of alcohol which can be taken daily by the average individual without doing harm is between one and two fluid ounces. This is contained in about two ounces of ordinary spirit, such as brandy or whisky, and in half a pint of the light wines, such as clarets and Burgundies, or in about a pint and a half of the ordinary beers and ales.

It is still a matter of dispute as to how alcohol is eliminated from the body, and whether any of it is destroyed in the tissues. The probable truth is that alcohol is oxidized in the body, the products being excreted in the urine. In small doses, alcohol stimulates the nervous system, reddens the lining membrane of the stomach, increasing the secretion of the gastric juice, and thus may in very small doses promote the appetite. When carried into the circulation, it increases the heart's action, and at the same time causes the smaller blood-vessels or capillaries to dilate. It is an unsettled question as to how far alcohol lowers the body temperature in health, but it is beyond question that it tends to lower the natural resisting power of the body against cold, and is in consequence unsuited for those exposed to great degrees of cold as in the Arctic regions. If taken too often, even in small doses, or taken in any large quantity at one time, alcohol instead of stimulating the nervous system actually depresses and paralyzes it, as evidenced by intoxication. In these circumstances the perception power of the brain is depressed or paralyzed, correct judgment is impossible, while speech is disordered and the emotions out of all control. If repeatedly taken to excess, alcohol delays digestion, causes catarrh of the stomach and bowels, accompanied by such degenerated conditions of both the liver and kidneys as to result in death. It is beyond question that, when taken in sufficient quantities to produce these effects upon the brain and nervous system, alcohol causes an immensity of harm; the physical, moral, and social

evils of intemperance are only too familiar to us all. But how far alcohol is beneficial or not when taken in small or dietetic doses is still a matter of controversy between the teetotalers and those who advocate moderation.

The evidence is overwhelming that in respect of physical effort a person can do quite as hard if not harder work without alcohol than with it; the experience of wars and expeditions in all climates, where abstinence was either enforced by order or by circumstances, shows that soldiers endure more fatigue, are healthier, and fight better without alcoholic stimulants than with them. On the other hand, it must be borne in mind that in ordinary life to many the cares and worries of business and existence are such that to them, after the labours of the day, a moderate amount of alcohol in some form or other is not only an advantage but almost a necessity. To the old and feeble, the use of alcohol is not less valuable. In all cases, however, it should be remembered that alcohol should never be taken during working hours with the idea that the body and brain are likely to do more work after it than before; the only time when it can be advantageously used is after the day's work is done; so taken, its influence is often to check tissue change and waste, to soothe and stimulate an exhausted brain with a removal of the sense of fatigue, and to promote digestion. Alcohol should never be taken fasting; its best effects are secured when taken with food, and at no meal more so than at the late dinner or supper.

The essential facts to be borne in mind are that the main action of alcohol is confined to the nervous system, and that its action is narcotic and not stimulant. True as this is, it must be admitted that there is nothing intrinsically bad about a narcotic and nothing intrinsically good about a stimulant. Each has its proper utility under given conditions. Alcohol has an undoubted food value from the point of view of its capacity to act as a fuel in the body, but at the same time it is a tissue poison, and for that reason its utility is merely that of a sedative or narcotic drug, to be used or taken only at long intervals. Its food value is suitable only in disease, exhaustion, and similar emergencies. As an aid to work, alcohol is physiologically unsound. On the other hand, the temperate consumption of alcoholic liquors may be considered physiologically harmless in the case of the majority of normal adults. It is, however, definitely injurious for children, for persons of nervous instability, and for those who have had severe head injuries or nervous shock.

Beer.—The usual definition of beer is, that it is a fermented infusion of malt flavoured with hops. This, however, is not quite correct at the present day, as sugar largely takes

the place of malt, and other vegetable bitters that of hops; so that probably a more accurate definition would be, to call it a fermented saccharine infusion to which has been added any wholesome bitter. Formerly the substitution of quassia, gentian, calumba, or any other bitter in place of hops was illegal, but now it is not the case, with the result that all kinds of bitters may be used provided they are wholesome. As a matter of fact, however, in the best beers even now, the only bitter used is hops.

Modern beers may be divided into two great groups, namely, the non-malt beers and the malt beers. What are called non-malt beers are those made by a yeast fermentation of an infusion of sugar, mainly derived from starch chemically or artificially converted, as by the action of sulphuric acid. Malt beers are the result of a similar yeast fermentation of an infusion of sugar, only in this case the sugar is derived from the natural conversion of grain starch by means of germination or malting. In both instances, the resultant liquor is an alcoholic one, in which a portion of the alcohol becomes transformed into aldehyd, and subsequently by a further oxidation changed into acetic acid. The essential points in brewing are the facts that the quantity of yeast to be added and the temperature at which fermentation is allowed to take place, vary with different kinds of beer; also that yeast works better when transferred from one kind of beer to another; and that the fermentation must be so regulated that the whole of the sugar contained in the wort is not transformed into alcohol, as if it is all so transformed the beer has no keeping power—that is, it would turn sour in the casks. This turning sour is due mainly to the passage of the alcohol into aldehyd and the subsequent oxidation of this into acetic acid.

There are many varieties of ales and beers, the chief being: *Pale* and *Mild Ales*, made from the finest dried malt and the best hops; the mild ale is usually sweeter, stronger, and less bitter than the pale. *Porter* is nothing more than a weak mild ale, coloured and flavoured with roasted malt. *Stout* is a richer and stronger kind of porter. The *German Beers* are fermented by means of sedimentary yeast as distinguished from the surface yeast used in England. Their fermentation is carried on at a lower temperature than in the case of British beers. They contain also less alcohol than the English, but are richer in carbon dioxide, and keep better. *Lager* and *Bock* beer is made from a stronger wort, and is proportionately richer in alcohol and malt extract. The *Belgian beers* are made with unmalted wheat and barley; they take long periods to ferment, doing so spontaneously, no yeast being added; as a rule, they are hard from the

presence of much acid. *Bottled beers* are all bottled while fermentation is going on, and owe their sparkling and frothing to the excess of carbon dioxide in them.

The chief constituents of ales, stouts, and porters are—alcohol, dextrin, sugar, hop resin or oil, glutin, acetic and lactic acids, carbon dioxide, mineral ash, and water. The alcohol in beer, varies from 1 to 10 per cent. in volume. The free acidity which arises chiefly from acetic, lactic, and malic acids, if expressed as acetic acid, ranges from 15 to 40 grs. per pint. The malt extract, which consists mainly of sugar, dextrin, and cellulose, varies from 4 to 15 per cent. Some beers have been known to be the cause of arsenical poisoning, as in the notorious epidemic in Lancashire in 1900. This arose from the employment of an arsenically tainted sulphuric acid for the manufacture of the sugar subsequently used for brewing the beer. Such a sequence of events is fortunately rare, but it brings into prominence the great need for scrupulous purity in all ingredients used in the preparation of foods and drinks.

Regarded as a food, the nutritive value of beer is small, though, of course, higher than other alcoholic drinks, owing to the large amount of maltose, dextrin, and other saccharine substances which it contains in the form of malt extract. In the main, its dietetic effects are those of alcohol, modified by the associated action of other ingredients. Beer appears to have some action peculiarly its own; this is generally attributed to *lupulin*, which is the active principle in hops. On some people, beer acts as a depressant, and, if taken in excess, it undoubtedly is a soporific or stupor producer. Beer also seems to exercise slight but continuous interference with tissue change, with a tendency to fatten and produce gout and rheumatism. When drunk to any excess, beer appears to have a retarding effect upon digestion.

In its general characters a good beer should be transparent with a red-brown colour, and possessed of a semi-vinous flavour. Formerly, many hurtful ingredients were added to beer as adulterants, but in the present day, practically the only adulterations are water with occasionally salt or alum. Salt is usually present in small amounts in the best beers, being derived from the water and other ingredients in making; but if present in excess of 10 grs. per gallon amounts to an adulteration. Alum is sometimes added to beer combined with salt, and sulphate of iron or even sugar in order to raise the density and give a "head" after dilution with water. Such beer soon undergoes secondary fermentation, and becomes sour, heady, and unwholesome. The quality of ale is most conveniently estimated by a determination

of the amounts of its acidity and its contained alcohol. For determining the acidity of beer, we need an alkaline solution of known strength, of which 1 c.c. is equal to 6 mgms. of acetic acid. The amount of this solution required to exactly neutralize a given quantity of beer is determined and expressed as acid in grains per pint. This, representing the *total* acidity of the beer, rarely exceeds 26 grs. per pint, more commonly is about 16 grs. per pint.

To determine the amount of contained alcohol and the original gravity of a beer, the following procedure is necessary: By means of a gravity bottle determine the specific gravity of the sample at 60° F. Next evaporate 200 c.c. of the beer down to about one-third, allow to cool, measure, and re-make up to its original volume with distilled water, and then determine the specific gravity of this de-alcoholized beer at 60° F. Deduct the gravity obtained before evaporation from that after it, and take the difference from 1000. Having obtained this figure, refer to the accompanying table of degrees of specific gravities, and read off opposite the number obtained the percentage of alcohol present.

Specific gravity at 60° F.	Volumes per cent. of alcohol.	Specific gravity at 60° F.	Volumes per cent. of alcohol.	Specific gravity at 60° F.	Volumes per cent. of alcohol.
1000·0	0·00	990·2	7·00	979·0	17·00
999·9	0·05	989·0	8·00	978·0	18·00
999·8	0·15	987·8	9·00	977·0	19·00
999·1	0·55	986·6	10·00	976·0	20·00
998·5	1·00	985·4	11·00	970·9	25·00
997·0	2·00	984·3	12·00	965·4	30·00
995·6	3·00	983·2	13·00	959·2	35·00
994·2	4·00	982·1	14·00	951·9	40·00
992·9	5·00	981·1	15·00		
991·5	6·00	980·0	16·00		

From the same data, practically, the gravity of the original wort from which the beer was brewed can be calculated. Taking the difference between the two gravities, obtained respectively before and after de-alcoholization, we obtain a figure or number which is called the approximate spirit indication. Next determine the acidity of the beer as a percentage of acetic acid: from the following acidity table, read off the spirit indication corresponding to this acidity. Add this figure to that of the approximate spirit indication, and we get what is called the true spirit indication.

TABLE FOR ASCERTAINING THE SPIRIT VALUE OF ACTIVE ACID IN BEER.

Percentage of acetic acid.	Corresponding degrees of spirit indication.									
	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
0·0	—	0·02	0·04	0·06	0·07	0·08	0·09	0·11	0·12	0·13
0·1	0·14	0·15	0·17	0·18	0·19	0·21	0·22	0·23	0·24	0·26
0·2	0·27	0·28	0·29	0·31	0·32	0·33	0·34	0·35	0·37	0·38
0·3	0·39	0·40	0·42	0·43	0·44	0·46	0·47	0·48	0·49	0·51
0·4	0·52	0·53	0·55	0·56	0·57	0·59	0·60	0·61	0·62	0·64
0·5	0·65	0·66	0 67	0·69	0·70	0·71	0·72	0·73	0·75	0·76
0·6	0·77	0·78	0·80	0·81	0·82	0·84	0·85	0·86	0·87	0·89

From the annexed table (pp. 201 and 202) read off the gravity (representing sugary extract which has fermented or become converted into alcohol and acid) corresponding to this spirit indication. If this figure be now added to the gravity given by the de-alcoholized beer (representing unfermented sugary extract), we get then the probable original gravity of the wort from which the beer was brewed.

Example.—Say a beer sample has yielded 0·04 per cent. of acetic acid, and that the first and second gravities were respectively 1016·47 and 1023·36; the difference between these gravities is clearly 6·89, and this taken from 1000 gives 993·11 corresponding in the alcohol table to 4·84 per cent. of contained alcohol. The original gravity of the wort would be calculated as follows: The difference between the two gravities taken before and after de-alcoholization we know to be 6·89, while the percentage of acetic acid is 0·04, corresponding by the acidity table to a spirit indication of 0·07. Then 6·89 *plus* 0·07 gives a true spirit indication of 6·96, which, by a reference to the other table, is equivalent to 28·6 degrees of gravity lost by fermentation. Then, as the second gravity, or that obtained after de-alcoholization and representing unfermented extract, is 1023·36, by adding this to 28·6 we get 1051·96 as the probable original gravity of the wort from which the actual beer sample was brewed.

Some idea as to the solids or amount of extract per cent. in a beer can be obtained if, after taking the specific gravity after de-alcoholization, the excess of gravity over 1000 be divided by 4; this gives an approximate conclusion as to the body of the beer; the more extract, the greater is the body of the ale. In the example given above, the extract would be calculated as being 23·36 divided by 4 or 5·75 per cent.

Wine.—The term wine is held to mean "the fermented juice of the grape with such additions only as are essential to the stability or keeping quality of the wine." This definition admits as wines those beverages which, made from grape juice, require to preserve them the addition of spirit, as in the case with some

TABLE SHOWING DEGREES OF SPIRIT INDICATION WITH CORRESPONDING DEGREES OF GRAVITY LOST.

Spirit indication.	Hundredths of a degree.									
Degrees and tenths.	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
4·0	15·10	15·14	15·18	15·22	15·26	15·30	15·34	15·38	15·42	15·46
·1	15·50	15·55	15·60	15·65	15·70	15·75	15·80	15·85	15·90	15·95
·2	16·00	16·04	16·08	16·12	16·16	16·20	16·24	16·28	16·32	16·36
·3	16·40	16·44	16·48	16·52	16·56	16·60	16·64	16·68	16·72	16·76
·4	16·80	16·85	16·90	16·95	17·00	17·05	17·10	17·15	17·20	17·25
·5	17·30	17·34	17·38	17·42	17·46	17·50	17·54	17·58	17·62	17·66
·6	17·70	17·75	17·80	17·85	17·90	17·95	18·00	18·05	18·10	18·15
·7	18·20	18·24	18·28	18·32	18·36	18·40	18·44	18·48	18·52	18·56
·8	18·60	18·65	18·70	18·75	18·80	18·85	18·90	18·95	19·00	19·05
·9	19·10	19·14	19·18	19·22	19·26	19·30	19·34	19·38	19·42	19·46
5·0	19·50	19·54	19·58	19·62	19·66	19·70	19·74	19·78	19·82	19·86
·1	19·90	19·95	20·00	20·05	20·10	20·15	20·20	20·25	20·30	20·35
·2	20·40	20·45	20·50	20·55	20·60	20·65	20·70	20·75	20·80	20·85
·3	20·90	20·94	20·98	21·02	21·06	21·10	21·14	21·18	21·22	21·26
·4	21·30	21·35	21·40	21·45	21·50	21·55	21·60	21·65	21·70	21·75
·5	21·80	21·84	21·88	21·92	21·96	22·00	22·04	22·08	22·12	22·16
·6	22·20	22·25	22·30	22·35	22·40	22·45	22·50	22·55	22·60	22·65
·7	22·70	22·74	22·78	22·82	22·86	22·90	22·94	22·98	23·02	23·06
·8	23·10	23·15	23·20	23·25	23·30	23·35	23·40	23·45	23·50	23·55
·9	23·60	23·65	23·70	23·75	23·80	23·85	23·90	23·95	24·00	24·05
6·0	24·10	24·15	24·20	24·25	24·30	24·35	24·40	24·45	24·50	24·55
·1	24·60	24·65	24·68	24·72	24·76	24·80	24·84	24·88	24·92	24·96
·2	25·00	25·05	25·10	25·15	25·20	25·25	25·30	25·35	25·40	25·45
·3	25·50	25·55	25·60	25·65	25·70	25·75	25·80	25·85	25·90	25·95
·4	26·00	26·04	26·08	26·12	26·16	26·20	26·24	26·28	26·32	26·36
·5	26·40	26·45	26·50	26·55	26·60	26·65	26·70	26·75	26·80	26·85
·6	26·90	26·95	27·00	27·05	27·10	27·15	27·20	27·25	27·30	27·35
·7	27·40	27·44	27·48	27·52	27·56	27·60	27·64	27·68	27·72	27·76
·8	27·80	27·85	27·90	27·95	28·00	28·05	28·10	28·15	28·20	28·25
·9	28·30	28·35	28·40	28·45	28·50	28·55	28·60	28·65	28·70	28·75

TABLE SHOWING DEGREES OF SPIRIT INDICATION WITH CORRESPONDING DEGREES OF GRAVITY LOST (*continued*).

Spirit indication.	Hundredths of a degree.									
Degrees and tenths.	0·00	0·01	0·02	0·03	0·04	0·05	0·06	0·07	0·08	0·09
7·0	28·80	28·84	28·88	28·92	28·96	29·00	29·04	29·08	29·12	29·16
·1	29·20	29·25	29·30	29·35	29·40	29·45	29·50	29·55	29·60	29·65
·2	29·70	29·75	29·80	29·85	29·90	29·95	30·00	30·05	30·10	30·15
·3	30·20	30·25	30·30	30·35	30·40	30·45	30·50	30·55	30·60	30·65
·4	30·70	30·75	30·80	30·85	30·90	30·95	31·00	31·05	31·10	31·15
·5	31·20	31·25	31·30	31·35	31·40	31·45	31·50	31·55	31·60	31·65
·6	31·70	31·75	31·80	31·85	31·90	31·95	32·00	32·05	32·10	32·15
·7	32·20	32·25	32·30	32·35	32·40	32·45	32·50	32·55	32·60	32·65
·8	32·70	32·75	32·80	32·85	32·90	32·95	33·00	33·05	33·10	33·15
·9	33·20	33·25	33·30	33·35	33·40	33·45	33·50	33·55	33·60	33·65
8·0	33·70	33·76	33·82	33·88	33·94	34·00	34·06	34·12	34·18	34·24
·1	34·30	34·35	34·40	34·45	34·50	34·55	34·60	34·65	34·70	34·75
·2	34·80	34·86	34·92	34·98	35·05	35·10	35·16	35·22	33·28	35·34
·3	35·40	35·45	35·50	35·55	35·60	35·65	35·70	35·75	35·80	35·85
·4	35·90	35·96	36·02	36·08	36·14	36·20	36·26	36·32	36·38	36·44
·5	36·50	36·55	36·60	36·65	36·70	36·75	36·80	36·85	36·90	36·95
·6	37·00	37·05	37·10	37·15	37·20	37·25	37·30	37·35	37·40	37·45
·7	37·50	37·55	37·60	37·65	37·70	37·75	37·80	37·85	37·90	37·95
·8	38·00	38·06	38·12	38·18	38·24	38·30	38·36	38·42	38·48	38·54
·9	38·60	38·65	38·70	38·75	38·80	38·85	38·90	38·95	39·00	39·05
9·0	39·10	39·16	39·22	39·28	39·34	39·40	39·46	39·52	39·58	39·64
·1	39·70	39·75	39·80	39·85	39·90	39·95	40·00	40·05	40·10	40·15
·2	40·20	40·25	40·30	40·35	40·40	40·45	40·50	40·55	40·60	40·65
·3	40·70	40·75	40·80	40·85	40·90	40·95	41·00	41·05	41·10	41·15
·4	41·20	41·25	41·30	41·35	41·40	41·45	41·50	41·55	41·60	41·65
·5	41·70	41·75	41·80	41·85	41·90	41·95	42·00	42·05	42·10	42·15
·6	42·20	42·25	42·30	42·35	42·40	42·45	42·50	42·55	42·60	42·65
·7	42·70	42·75	42·80	42·85	42·90	42·95	43·00	43·05	43·10	43·15
·8	43·20	43·25	43·30	43·35	43·40	43·45	43·50	43·55	43·60	43·65
·9	43·70	43·75	43·80	43·85	43·90	43·95	44·00	44·05	44·10	44·15

wines from Spain and Portugal; but it excludes the so-called British wines, which are not made from the juice of the grape at all, and those wines from other countries, which are fortified with spirit when they require no such addition.

When the sugary juice of a fruit, such as the grape, is left to itself at a moderate temperature, fermentation takes place from the influence and action of germs present in the air; this process differing very much from that in the making of beer, when the starchy or sugary infusion or wort is boiled, and then yeast added to make it ferment. During the fermentation of the fruit juice, a part or whole of the sugar is converted into alcohol. Various ethers, which give the characteristic flavour or bouquet to wine, are formed, as well as acetic, malic, succinic, and other acids. The essential acid of wine is tartaric acid; much of this crystallizes in the casks as cream of tartar or tartrate of potash. The newer wines contain aldehyd, which is very intoxicating; later on this gets oxidized into acetic acid, and if exposed to the air long enough, all the alcohol in a wine will be converted into this acid so as to practically become ordinary wine vinegar. Much of the colour, taste, and character of wines depend upon how far they are made from the grape juice only, or how much this is mixed with the seeds and skins of the fruit. The seeds are rich in tannin and a bitter principle, while the skins yield a colouring matter, some flavouring principle, and tannin.

With regard to the amount of alcohol which a wine contains there is no constancy. All wines can be divided according to their alcoholic strength into two classes: the natural wines, containing from 6 to 13 per cent. by weight of alcohol; and the fortified wines, containing from 12 to 22 per cent. by weight of alcohol. The limit of alcoholic distinction between these two great classes of wine will be more readily understood if it be borne in mind that during the fermentation of any sugary liquid or mass, that process at once ceases when the alcohol formed reaches 14 per cent., so that any excess of alcohol over that amount must, of necessity, have been added artificially. The ports and sherries are all largely fortified with added alcohol; while many of the inferior clarets and champagnes are subject to very similar additions. The strongly alcoholic and fortified wines are slow to undergo change, hence keep well; but the lighter and natural wines deteriorate rapidly when exposed to air.

Like the alcohol, the sugar in wine varies much, being for the most part in the form of fruit sugar. Sherries generally contain about 8 grs. to the ounce. In Madeira it varies from 6 to 66 grs. per ounce; in port, from 12 to 28 grs. In champagnes the average is about 24 grs., but many of the dry champagnes contain none.

Wine is acid from the presence of free acid and acid salts, such as tartrate of potash. Wines which have been "plastered" or treated with gypsum or plaster of Paris to clear them, as is the case with many sherries, are deteriorated, owing to the loss of their tartrates. The chief acids are tartaric, acetic, malic, tannic, succinic, carbonic, and fatty acids. The usual acidity of wines, in terms of tartaric acid, is about 2 grs. per ounce in sherry, 3 grs. in champagne, 4 grs. in port and the better kinds of claret, and 6 grs. or more in the inferior clarets. The tannic acid is derived mainly from the seeds and skins of the grape; it is largely present in new port, less so in Madeira and the Rhine wines. The amounts of alcohol and degrees of acidity can be determined in wines in the same manner as explained for beer. It is to the mutual reactions of the acids and alcohols in wine that the formation and presence in them of ethers is due, and it is really to these latter that wines owe their special value as stimulants. The colouring matter of wines is derived mainly from the grape skins; by nature it is greenish or blue, but becomes violet or red by the action of the free acids in the wine. As wine ages, changes occur, resulting in a precipitated combination of the organic bodies with tannic acid, whereby the wine becomes pale and less astringent. Occasionally, in the inferior wines, artificial colouring matter is added in the form of the many varieties of aniline dyes, logwood, cochineal, etc. The adulterations of wine are mainly in the direction of added spirit, artificial colouring, and "plastering" to secure clearness and dryness.

The term "dryness" as applied to wines is meant to express a flavour which is not that of sweetness. It has already been explained that the fermentation of grape juice in the formation of wine is the result of a vegetable growth—that of a microscopic fungus which the *must*, or juice of the grape, obtains spontaneously from the atmosphere. Two distinct effects follow the growth of this fungus or process of fermentation: one is, the sugar of the must or grape juice is converted into alcohol; secondly, the greater part of the albuminous or nitrogenous part of the must is consumed as food by the fungus. If left alone, the fermentation goes on until either all the sugar is used up or until the supply of sufficient albuminous matter is exhausted. Now, it will readily be understood that the relative proportions of these present determine which of the two gets exhausted first; and if the sugar is used up before the albuminous food of the fungus, a dry or not sweet wine is produced, while if the nitrogenous food is exhausted first, the remaining unfermented sugar produces a sweet wine. Since the juice of the ripe grape contains from 10 to 30 per cent. of sugar, there is a very wide range.

A large number of people dislike sweet wines, hence the demand for what is called a dry wine. From what has been stated as to the difference in origin of a naturally sweet wine and a naturally dry wine, it will be apparent that the poorer the grape the drier the wine made from it; but the yield from a poor grape is less than that from a rich one, hence naturally dry wine costs more to produce than naturally sweet wine. It will also be apparent that the conversion of naturally sweet wines into dry ones will not be difficult, and since there is a demand for dry wines the artificial conversion is frequently performed. It is carried out either by making the wine from unripe or poor grapes, in which case the yield of alcohol and flavour are both low; or it is done by adding some nitrogenous material such as gelatin, isinglass, or white of egg to the must, so as to feed the yeast fungus until all, or nearly all, the sugar in the grape has been converted into alcohol. This procedure is sometimes called *fining*, in the wine trade, and is the least objectionable of all methods of artificial drying, being, as it is, almost identical with the natural cause of wine dryness. Unfortunately, there are other methods adopted which are less commendable but more common. These consist often in making an imitation of the natural dryness of wine by adding factitious salts and fortifying with alcohol. The sugar still exists as largely as before, only its taste is disguised.

Perhaps the most general method of increasing the dryness of a given wine is that of adding mineral acids and mineral salts, more particularly gypsum. This is technically known as "plastering," because gypsum is plaster of Paris. This being largely sulphate of calcium modifies the chemical characters of the wine by decomposing the cream of tartar or potassium tartrate into calcium tartrate, potassium sulphate, and free tartaric acid, at the same time altering the colouring matter and changing the neutral organic compounds which exist in grape juice. The use of gypsum materially clears a wine, making it look brilliant; this is explained by the fact that the resulting sulphate of potash is much more soluble than the antecedent tartrate of potash. To a certain extent, after the addition of gypsum, much of the tartaric acid of wine is replaced by sulphuric acid, a body which renders wine, so altered, distinctly unsuitable for daily use. The sherries suffer the most from plastering—so much so, that some chemists advise that the plastering of wines should be called adulteration.

The nutritive value of the wines is small, and in the main subsidiary to the stimulating properties of their contained alcohol. The clarets and lighter wines are more or less antiscorbutic, owing to the presence of the organic acids. Port and sherry appear to predispose to gout. The presence of some albuminous principle

in wine may give it a slight nourishing value, but in favour of such a view the evidence is small.

Of all the alcoholic beverages, spirits contain the largest amount of alcohol. They are all made by the distillation of alcohol from the fermentation of various saccharine or starchy materials. The more common spirits in this country are brandy, whisky, rum, and gin. The basis of all of them is ethylic alcohol, mixed with water; but they all contain other alcohols, usually classed together under the name of fusel oil, various compound ethers, and fragrant bodies produced during distillation. It is the varying proportions of these latter which give the respective spirits their characteristic taste and aroma. After being kept for some years, spirits become mellowed or softened down; this was formerly supposed to be due to the diminution of the so-called fusel oil, but it is now more generally regarded as due to a lessening both in quantity and quality of the empyreumatic or flavouring substances.

Brandy is made by the distillation of fermented grape juice. When first distilled it is colourless, but gradually darkens with age, though too often artificially coloured by means of burnt sugar. Pure brandy consists of water, alcohol, acetic acid, acetic and œnanthic ethers, a volatile oil, colouring matter, and tannin. It usually contains from 46 to 55 per cent. of alcohol. The best kinds come from France, the more inferior from Spain, Portugal, and Italy. The chief adulterations are water, cayenne pepper, burnt sugar, and acetic ether. Some of the cheaper brandies are not made from grape juice at all, but are mere imitations, made from corn spirit, flavoured and coloured. According to Blyth, a very usual process of making brandy artificially in England is to add to every 100 parts of proof spirit from ½ to 1 lb. of argol, some bruised French plums, and a quart of good Cognac; the mixture is then distilled, and a little acetic ether, tannin, and burnt sugar added afterwards.

Whisky is really one of the corn spirits, being made from malted grain. The more inferior kinds are prepared from oats, barley, or rye, or from potatoes mashed up with malted barley and then roughly distilled and burnt in order to give it the peculiar smoky flavour characteristic of some varieties. Whisky usually contains from 40 to 50 per cent. of alcohol. Its adulterations are much the same as those of brandy.

Rum is a spirit obtained by distillation from the fermented skimmings of sugar-boilers or the drainings of sugar-barrels (molasses). Like brandy, it is colourless when first distilled, but it is later on artificially coloured with burnt su[illegible] [illegible]m is chiefly made in Jamaica, and, owing to the habit [illegible] few

The *flap-trap* is a hinged valve allowing water to pass in one direction: it was expected that this would prevent the reflux of sewer-air, but it has been found to act very imperfectly, and is useless to prevent sewer-gas returning.

The *ball-trap* is one in which a ball rises with the rise of water and closes an orifice; it is a very imperfect form of trap.

Gully-traps should be at least 18 inches from the wall of the house, and their superficial surface should be as small as possible, so as to diminish the evaporation of water.

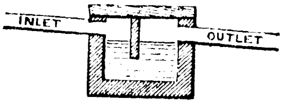

FIG. 46.—Dipstone-trap.

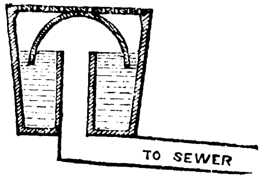

FIG. 47.—Bell-trap.

Siphon-traps, however perfectly made, cannot be relied on to prevent the passage of sewer-air. Water alone cannot always resist the pressure of air, and even if it accomplishes this, it will absorb foul gas from below and emit it above; hence the absolute necessity for the disconnection and the ventilation of the sewers.

To prevent the deposit of grease or sand in the drain-pipe, scullery sinks require to be provided with a grease-intercepting chamber; if grease is allowed to flow into the drain, it may gradually stop up the pipe by adhering to the sides, and is then difficult to remove. This chamber is generally made of hollow stoneware, with a tight iron cover, and ventilated. The hot greasy water from the sink is discharged at the bottom of the chamber, the grease is then cooled and rises to the surface for removal, the sand sinking to the bottom, while the water passes away to the drain. The grease and sand must be removed every second or third day.

Grease-traps may be classed with ordinary gully-traps. They should not generally be used for ordinary kitchen or scullery sinks, but may be necessary when a large amount of grease is passed off, as in hotels, etc. Grease-traps partake of the nature of cesspools, and should not be used when avoidable.

Concerning traps generally, engineers look suspiciously on every one of them, and endeavour to render them unnecessary by thorough ventilation and disconnection of the drains.

The essentials of a good trap are that the water stands at least

three-quarters of an inch above the openings, that the trap itself be self-cleansing, that is, all the contained water should be effectually changed by every flush. A trap is only efficient so long as it contains water: if therefore a trap exposed to the air, such as a gully-trap or a hopper closet trap, is not in constant use, especially in hot weather, the water evaporates, and direct communication is established with the drain. In dry weather it is desirable to see that unused traps are charged with water.

Waste-pipes discharging water from kitchen sinks, sculleries, etc., and bath-waste pipes carrying away water from baths, should not connect directly with any drain, but must discharge into the open air, over a good water-trap. Waste-pipes should also have a siphon-trap on their course with a 3-inch water-seal. They should *not* be connected with any soil-pipe.

Waste-water pipes are best made of lead, and should be sufficiently strong to resist the action of expansion and contraction, caused by hot and cold water; they are generally 2 inches in diameter.

Rain-water pipes should also discharge their contents over a trapped gully, so as to be completely cut off from the drain.

The Examination of Drains.—In practice this amounts to the application of certain tests for the determination of soundness. Two chief methods of testing drains are in use, namely, by smoke or volatile agents, and by water. The smoke-test consists in filling the drain or soil-pipe with smoke, the assumption being that this will find its way through any leak, faulty joint, or trap, thus indicating the site of the defect. The smoke may be forced into the pipe or drain from a pumping apparatus, or be produced within the drain from a specially prepared grenade or rocket. An alternative procedure is to pour a table-spoonful of oil of peppermint, mixed with hot water, either down the highest water-closet or down the pipe at the highest point available; as this is a very volatile and pungent oil, there is no difficulty in tracing where the odour is emitted, and so detecting the leak. Although convenient for testing traps and fittings above ground, these tests are of little value in the examination of underground pipes. The only absolutely trustworthy test for drains is the water-test. Having plugged up the lower end of the drain by a suitable water-tight stopper, the drain is gradually filled with water. If the water-level remains constant for half an hour or more, the drain may be considered sound and water-tight. If it will not fill, or the level falls rapidly after filling, there is leakage somewhere, and it will be necessary to open it up and repair, or perhaps relay the drain.

In applying the water-test to drains, it must be remembered

that each foot of water-head exercises a pressure within the pipe or drain of 0·432 pound on the square inch, or to find the head of water required to obtain any given pressure, this, in pounds per inch, if multiplied by 2·31, will give the head in feet. It is doubtful whether, in the routine examination of drains, it is desirable to put any considerable pressure on the drain as defects may be caused which did not before exist. If stoppage of the drain occurs, and there are manholes or access pipes provided, the spot where the obstruction takes place can be easily localized; but if no such arrangement exists, the drain or pipe will have to be broken in one or more places, until the point of stoppage is found. Brisk flushing with water will generally remove any obstruction. Stoppage may be caused from imperfect laying of the drain, from improperly finished-off joints, so that a rough surface is left on the inside of the pipe; or roots of trees may find their way through the joints of earthenware pipes, when clay is used for jointing. The most frequent cause of stoppage, however, is that various articles are improperly thrown down the water-closet, and gradually fill up the pipe.

Sewers are the trunk canals into which the house-drains empty their contents. The system of sewerage now generally adopted in England is the 1"combined system;" in this system the surface drainage and rain-water are carried off by the same channels as the sewage. Sometimes separate drains are provided to carry of the rainfall; this is called the 2"separate system," and involves two sets of drains; one to carry off the rain and storm waters, the washing of streets and open spaces; the other to carry off the sewage. The former discharge their contents into the nearest river or watercourse; the latter will convey the sewage to be treated by some one of the methods described subsequently. The advantages claimed for this are that smaller sewers are required, and that the amount of sewer-water is less, richer in quality, and more regular in flow; no storm-waters enter the sewers to flood the lower districts of the town, and no road detritus is washed into the sewers. The disadvantages are that the drainage system is practically duplicated, and rain-water washes away much that would pollute a stream; the scouring effect of rain on sewers is also lost, but this is a doubtful objection. Adoption of either plan must depend on local circumstances.

Considerable economy could be effected, in connection with drainage of small dwellings, by adoption of a common drain or sectional drainage. This common drain to collect the drainage from not more than 15 houses and to deliver at one point into the main sewer, instead of requiring each house to have its drainage system separately connected. The latter involves separate dis-

connecting traps, manholes, and ventilation arrangements for each house with a separate connection cut across the road to the sewer. Where there is a duplicate system with one connection to the sewer and another to the rain-water system the savings are increased. The adoption of the common drain system from 14 to 15 houses to the sewer is particularly suitable for municipal housing schemes in which the local authority is not only the owner of the property but also, under recent legal decisions, responsible for maintaining the common drain.

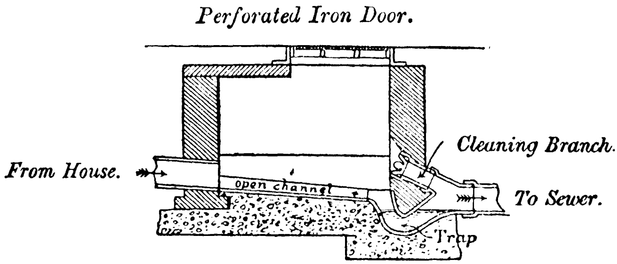

FIG. 48.—Disconnecting manhole.

In every system of sewage two objects are generally aimed at: first, sewage has to be removed, and this should be done by impervious pipes, such as glazed stoneware or iron, or brick-work laid in cement, very carefully laid and jointed; and secondly, when necessary, the subsoil must be drained. This may require pervious drains or drain-sewers. If pipe-sewers only are used, the subsoil water remains unaffected, except so far as a small portion may find its way along the channels formed by the pipe. Sometimes pervious drains of earthenware are laid down to carry off the subsoil water.

Sewers up to 18 inches diameter are generally made in stoneware and are circular in section. Concrete pipes are also largely used for the larger diameters. These are preferable to stoneware and generally cheaper. Cast-iron pipes are also used under certain circumstances, they should be coated with Angus Smith's preservative to prevent corrosion. If fluctuations in the amount of sewage are great, an egg-shaped sewer is preferable to the circular form; but if there is sufficient sewage to keep sewers constantly running, say half full, the circular section is best, being cheapest and strongest. If stoneware pipes are used, it is advisable to lay a foundation of concrete which supports the pipes in their length, and not at the sockets only. The pipes should also be packed at

their sides to prevent their being crushed. The joints must be cemented, and not puddled with clay, care being taken that the cement does not get inside the pipes, forming projections in the sewer against which solid matters will lodge and obstruct the flow of the sewage.

To avoid deposition of sediment, sewers should be laid in as straight lines as possible and with a regular fall; junctions should be made oblique, so that the sewage may enter in the direction of the flow. The junction of drains is made by a special form of pipe, which may be either single or double. If the sewer curves it should describe a wide sweep, the radius of the curve not being less than ten times the cross-sectional diameter of the sewer. Inspection of pipes may be provided for by a manhole or by the arm of a disconnecting trap (Figs. 48, 49, and 50).

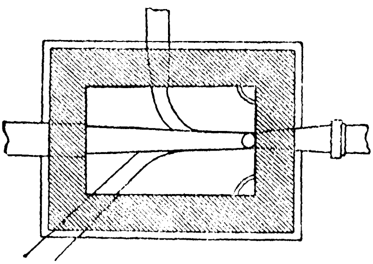

FIG. 49.—View of inspection chamber from above.

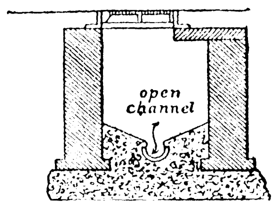

FIG. 50.—Sectional view of an inspection chamber.

Main sewers are generally made of well-cemented brickwork and egg-shaped in form, to give greater hydraulic depth, and, therefore, increased velocity with a small quantity of fluid. The egg-shaped sewer is formed by two circles touching one another; the diameter of the upper circle equals twice that of the lower, so that the invert is the narrowest part. This form of sewer secures the maximum scouring effect with the minimum quantity of water.

To secure a uniform flow, it is necessary to diminish friction as much as possible; and this is found to be least in this form of sewer, as the wetted perimeter is proportionately reduced, instead of being, as in every other form, relatively increased. The interior should be smoothly finished, and the sewer itself quite impervious and free from any inequality.

At each principal change of line or gradient there should be arrangements for inspecting flushing and ventilation; at all junctions and curves the fall should be increased to compensate

for friction; the principal sewers should have special overflow pipes for any excess of rainfall; no junctions should be at right angles, nor opposite other junctions; tributary sewers should deliver in the direction of the main flow, and should have a fall into the main at least equal to the difference between their two diameters; pipes of small size should always join on to pipes of larger size; if the tributary joins the main sewer below the level of the sewage in the latter, deposits are produced in the branch. Street gullies are generally provided to prevent the entry of gravel and solid matters into sewers. The debris collects in the gullies, while the water flows off by an opening to the sewer placed on a higher level, and the deposit is removed at intervals.

Fall of Sewers.—The amount of fall that should be given to sewers, or the inclination at which they should be laid, will depend upon the velocity of the current that it is desired to attain. To prevent deposit, in drains of 4 and 6 inches diameter the velocity should not be less than 3 feet per second; for drains of larger size a less velocity will suffice.

The inclination or fall required is 1 inch in 40 for 4-inch drain, and 1 in 60 for a 6-inch drain, and for sewers from 1 in 244 to 1 in 784 according to size. Too deep an incline has a tendency to cause the water to run away too forcibly, leaving the solid matter behind. If the fall is less, or if deposits occur, special means for cleansing are required. This is usually accomplished by manholes placed at intervals, the sewers running in straight lines from manhole to manhole. When the current is feeble and deposits are liable to occur, automatic flush-tanks may be placed at the upper end of the sewer. Flushing is chiefly required in sewers with insufficient gradients, at "dead ends," and in hot dry seasons when the flow of sewage is smallest and decomposition most rapid. Automatic flush-tanks may be used for this purpose; they act by siphonage, so that the whole cistern empties itself with a sudden flush when the action is once started (Fig. 51).

The action of the cistern is as follows: The base of the tube dips into the trapping-box, then, as the water rises in the cistern, it compresses the air in the tube. The water continues to rise in the dome of the siphon until it reaches the level of the lip, when on overflowing, the water falls down the centre of the tube, carrying with it a certain amount of air. This action continues until a partial vacuum is formed in the inner tube, and the siphonic action due to the pressure of the atmosphere is commenced, when the whole contents of the cistern are discharged with great velocity. An important point to bear in mind is that, on fixing

one of these cisterns, the dome of the siphon must be removed, and a few gallons of water poured into the lower chamber so as to form a trap.

The simplest formula for calculating velocity of flow through circular sewers or pipes is the following:—

$$V = 55 \times \sqrt{D \times 2F}$$

V = velocity in feet per minute.
D = hydraulic mean depth in feet.
F = fall in feet per mile.
V × sectional area of current of fluid, in sq. feet, = discharge in cubic feet per minute × 6·23 = gallons per minute.

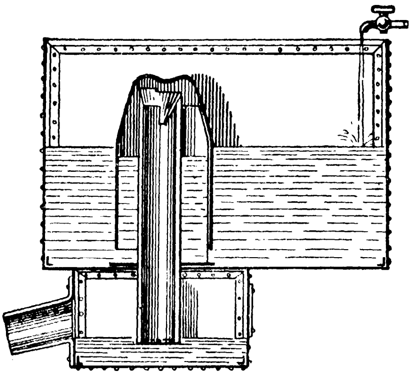

FIG. 51.—Field's flush-tank.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. Fall in fractional parts is converted into fall in feet per mile by dividing 5280 (number of feet in a mile) by the denominator of the fraction. Thus a fall of 1 foot per mile = 1 in 5280; 10 feet per mile, 1 in 528, and so on.

The hydraulic mean depth of a pipe of any shape equals the section area of the current of fluid divided by the wetted perimeter. The wetted perimeter is that part of the circumference of the pipe which is in contact with the fluid. The hydraulic mean depth in circular pipes, running full or half full, is one-fourth of the diameter.

The area of an egg-shaped sewer can be calculated by squaring the radius of the larger circle and multiplying by

4·6; the discharge in cubic feet per second for egg-shaped sewers flowing two-thirds full can be calculated from the formula $Q = 35\sqrt{d^5\frac{f}{l}}$, where d is the diameter of the larger circle, f is the fall, and l is the length. The velocity of flow in feet per second through an egg-shaped sewer can be expressed as being $128 \times \sqrt[10]{H^7} \times \sqrt{F}$, where H is the hydraulic mean depth, F is the fall, and 128 is a constant derived from the ratio of the coefficients for acceleration from gravity and for roughness of surfaces.

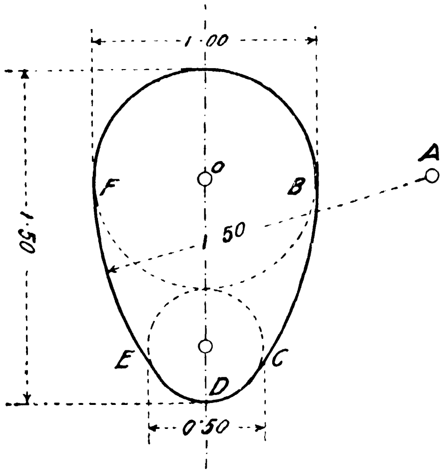

FIG. 52.—Egg-shaped Sewer.

Sewer Air.—In well-constructed sewers, where there is no deposit and the sewage is allowed to flow away without any obstacle to the outlets, the air is much better than might be expected. Observations indicate that the carbon dioxide is about twice, and the organic matter, estimated by the permanganate process, about three times as great as in the outside air at the same time; while the number of micro-organisms is less in sewer air than in the outside air. The excess of carbon dioxide is probably due to the oxidation of the organic matter in the sewage and in the sewer air, and, in part, to the diffusion into the sewer of air from the neighbouring soil. The few micro-organisms present, compared with the external air, is explained by the tendency these have to be deposited on the damp surfaces of the

sewers; with ordinary air-currents they are not disturbed or given off to the surrounding atmosphere; those present nearly all come from the outside air, their number being directly proportional to the number present in the external air at the time. In the absence of splashing or bursting of bubbles due to fermentation in the sewer, there is little ground for supposing that the micro-organisms in sewage become disseminated in the sewer air. In badly constructed sewers, or where deposits take place which undergo putrefaction, such favourable results are not found, and disease has been traced to the entry of infected sewer gas into houses through untrapped drains and openings into them. A distinction must be drawn between sewer air and sewer gas; the former is generally without smell and harmless, while the latter is always the result of stagnation, deposit, and putrefaction.

Ventilation of Sewers.—Sewers cannot be constructed air-tight on account of the very numerous openings into them; the tension of the air is generally not very different from that of the atmosphere outside, while the movement of the air is usually upstream, except where the depth of flow is considerable when the movement may be reversed. Certain conditions, however, are present which produce movement of air in sewers, the chief being—the variation in temperature in the sewer and in the external air; barometric pressure; the passage of hot water from houses or manufactories, causing a rise of temperature in the sewage and consequent expansion of the air in the sewer; the blowing off of steam, which increases the temperature and pressure suddenly; and the sudden increase of water flowing into the sewers. Any of these conditions may expel air from the sewer or draw air in from the external atmosphere. Tidal water in sewers is not so liable to cause violent movements of the air in them, as the rise of the tide is gradual. The question of the best methods of ventilating sewers is a very vexed one, as movement of air in sewers depends upon the many conditions mentioned above.

The simplest plan for ventilating sewers is by means of a shaft from the crown of the sewer to the surface of the street or road above, where it is covered by an iron grid. The mud and gravel which may fall through the grid is caught in a tray placed beneath the grating, but which allows the free passage of air around it. One such opening is placed commonly at intervals of a hundred yards or so. This system has been subjected to much criticism, mainly on account of the fact that it favours the discharge of objectionable gases from sewers more or less immediately under the noses of passers-by. As a routine practice, this plan of opening ventilating grids at road level is to be discouraged.

A preferable method is to locate along their course at suitable intervals tall iron shafts, provided with rust pockets, and carried sufficiently high as to permit of the escape of air and gases at a level well above the roofs of houses. As a matter of fact, however, if sewers are well constructed, have sufficient fall and flush of water, obviating the local accumulation of decomposing material, there should be no accumulation of foul gases. These ideal conditions, however, are not always existent; in which cases the only way to cope with the nuisance from sewer emanations is by abolishing dead ends of sewers or ventilating them, by erecting pipe ventilators in substitution of offensive gratings at street level, and the free admission or circulation of air in the sewers. The latter detail will do good by favouring oxidation of any putrescent matter and by diluting any offensive gases evolved. It has been suggested to solve this question of sewer ventilation by the abolition of the intercepting trap on the house-drain between the sewer and the house, thereby converting every house-drain and the soil-pipes discharging thereto into so many sewer ventilators. The main objection to this proposal is that it would destroy the drain isolation, which is now possible, of each house from the rest of the houses of a district. Moreover, as we cannot rely absolutely upon the soundness of every sanitary fitting in individual houses, the risks of sewer gas gaining direct access into dwellings would be considerable. It is true the intercepting trap is not an ideal sanitary appliance, but we have to choose between two evils, namely, having sewer gas laid on to the house, or having the efficiency of the house-drain somewhat interfered with; and the latter is the lesser evil.

In circumstances where there is a sectional drainage and a common drain serving 14 or 15 houses there should be one connection to the sewer from that common drain, with an intercepting trap and manhole on the common drain within the section drained as near as convenient to the junction with the sewer. The system should be ventilated by a fresh air inlet or vent pipe placed at the manhole containing the intercepting trap, also another air inlet at the head of the common drain, while each separate block of dwellings must have a vent pipe at or near the highest point of the common drain adjoining, the vent to be carried up clear of the eaves of the building. A manhole should be provided where two common drains form a junction, and inspection chambers or rodding eyes so placed that no drain exceeding 100 feet in length is without means of cleaning or ventilation. Rodding eyes must be provided also where a change in direction of the drain or a branch connection renders it desirable. All pipe connections must be by oblique bends or

easy curves. All connections from the dwelling should be bought into the w.c. branch drain as near the buildings as possible, so as to reduce the number of connections to the common drain.

Pneumatic Methods of removing Sewage.—These are practically three in number, namely, the Liernur, the Berlier, and the Shone systems. The first two are extraction methods working by means of a vacuum produced from a central air-pump station. These systems need specially constructed pipes and tanks or reservoirs, all being air-tight. They are complicated systems, practically never used in this country, and only needed in low-lying districts where suitable sewer gradients are difficult to secure. The Berlier system has the advantage of being more or less automatic in its working. The Shone system is really a device for raising sewage from one level to another, when the ground is very flat and a proper fall for the sewers cannot be secured. It works by compressed air generated at a central station and laid on in pipes to ejectors provided at various points. We are disposed to think that as good results are obtainable by steam pumping.

Disposal of Sewage.—This is still one of the most difficult problems of the day. Although the question of the disposal of sewage is distinct from that of its removal, yet the method of disposal is dependent, to some extent, upon the method of removal. In the dry method of removal the final disposal of the fæcal matter is mainly as a fertilizer or manure upon cultivated land. If the removal is by water, the ultimate disposal of the sewage may be without any attempt at purification as by discharge into the sea, running water, or into a cesspool; or it may be subjected to various methods of purification, such as separation of the solid and liquid parts either by subsidence or precipitation by chemicals, filtration through land, or various artificial media, and bacterial methods. The final effluent being discharged either on to land, or into the sea, or into some suitable stream or river.

Discharge into the Sea.—Under certain circumstances crude sewage may be discharged directly into the sea without nuisance. The outfall sewer must open always below the level of the water at all states of the tide; further, care must be taken to carry the sewage well out to sea, so that it may not return with the tide and be deposited on the fore-shore. Tidal currents and prevailing winds must be studied and taken advantage of to prevent this; also the outlet of the sewer should be protected by a tide flap opening outwards, to prevent ingress of tide and wind blowing up the sewer; the tide will block sewage at certain times, and this, in the case of low-lying towns, necessitates a "tank sewer," to

store the sewage that flows down during this period; but with this method, decomposition and evolution of gas and ammonia compounds are very liable to take place; it requires special attention.

Discharge into Rivers, etc.—This is prohibited by the Rivers Pollution Acts of 1876 and 1890. It is illegal to pollute any stream or river by allowing crude sewage to flow into it.

The Cesspool System.—This system as a means of disposing of crude sewage must be regarded only as temporary and partial; it provides for the immediate removal from the house of the excreta and foul waters, but only to a short distance, where it is received into a cesspool, from which the deposited solids must be removed. Cesspools are generally constructed of brick, and in the majority of cases the solid matters only are retained, the liquids passing into the surrounding subsoil and infiltrating it for some distance around. In some cases, to meet the requirements of the local authorities, the cesspool is lined with cement, so as to be impervious, and in this case an overflow-pipe must always be provided, when the question of dealing with the liquid has to be further considered.

The porous cesspool or dead-well is a method available only in a country place. In this system the surrounding soil gets polluted, and the water-supply must not be derived from anywhere near; the amount of percolation depends largely on the nature of the soil.

Cesspools should be placed at least 50 feet distant from any dwelling, and 100 feet or more from any well, spring, or stream, according to the nature of the subsoil and the trend of the movement of the underground water. They should always be at a lower level than the well from which the drinking water is taken, and to leeward of it, so as not to pollute the saturated portion of the permeable stratum above the well. They should be ventilated and emptied at regular intervals; it is often found convenient to utilize the liquid contents, by distributing this over the gardens or adjoining fields, and for this purpose a small hand-pump is usually attached, connected with a distributing-pipe or channel. Complete disconnection of the house-drains by proper traps and efficient ventilation are necessary to make this a sanitary method.

Purification of Sewage.—This presents great difficulties, and many methods have been suggested and tried with varying success. For the complete purification of sewage, three processes are involved: first, clarification; secondly, an alteration of the chemical constitution of the organic putrescible matter in solution in sewage, whereby it will not undergo any further putrefactive changes; thirdly, the removal of disease-producing bacteria.

These results are not obtained equally by the various methods which have been suggested. The more important are the following: chemical treatment, land treatment, and biological methods.

Chemical Treatment.—The processes suggested for the purification of sewage under this head are mainly precipitation methods, aiming at a more copious and rapid clarification of the crude sewage than can be effected by subsidence alone. One of the principal substances used for precipitating or clarifying sewage is lime. The quantity used depends on the character of the sewage, and varies from 5 to 10 grs. or more of quicklime for each gallon of sewage. If the effluent is made alkaline by the addition of too much lime it undergoes putrefaction rapidly; it has been attempted to prevent this by adding chloride of iron to the quicklime, by which means purification is delayed but not prevented; the process is simple and cheap, but as the organic matters in suspension only are acted on, it has failed to produce either a valuable manure or the purification of the offensive liquid. Precipitation has little effect on the removal of microbes, pathogenic or otherwise.

Among other processes which have been tried in different places may be mentioned those which employ lime and alum, lime and protosulphate of iron, also the ferrozone and alumino-ferric precipitants. In London a chemical process has been applied to the sewage before its discharge into the sea. This consists in adding 5 grs. of lime and 2·5 grs. of protosulphate of iron to every gallon of sewage; it produces an average reduction of 18 per cent. of dissolved oxidizable organic matter.

To ensure complete clarification of the sewage by chemical precipitants, the sewage must be fresh and the larger solids strained from it before the chemicals are added. The precipitants are added before the sewage arrives at the subsidence tanks, which must be sufficient to hold the dry weather flow for 24 hours. The tanks are arranged in series so that the sewage may pass slowly but continuously through two or four tanks before the supernatant liquid escapes into the effluent channel. When the tanks are full the flow of sewage is stopped and then allowed to rest in the tanks for from two to four hours so that it may deposit its sludge. The supernatant clarified liquid is then drawn off. In order that the treatment of the sewage may continue whilst the deposited sludge is being removed, there is always a second or even third series of tanks provided. The sludge has to be quickly removed and the tanks thoroughly cleaned out before being refilled. The sludge is very putrescible and possesses very little manurial value and often difficult to dispose of. It contains 90 per cent. of water, and is composed of the mineral and organic

matters precipitated from the sewage. When pressed in a filter the amount of water is reduced to 40 per cent. The pressed sludge is sold or given away as manure. A preferable way is to dry the sludge cakes by heat and then grind them into a powder; in this form the sludge is more manageable as a manure.

Occasionally, deodorants or antiseptics are added to sewage as well as the chemical precipitants. Examples are the addition of manganate of sodium and sulphuric acid, also a mixture of milk of lime and herring brine known as the Amines process. On the same principle of deodorization, attempts have been made to purify sewage by electrolysis which generated hypochlorous acid by decomposing the chlorides of sodium and magnesium normally present in sewage. Another effort on the same lines was the addition of electrolyzed sea-water to sewage. None of these methods are reliable, and moreover are costly to carry out.

The sludge having been deposited in the sewage tanks, the next question is what is to be done with the effluent or clarified sewage? The effluents obtained usually by chemical precipitation of sewage are fairly satisfactory. They contain very little suspended matter and much of the organic material of the original sewage has been precipitated and retained in the sludge. If passed into a river or stream whose volume is at least ten times greater than that of the effluent, and which is not used below the point of discharge as a source of drinking water, practically no nuisance or harm will result. This ideal arrangement is rarely possible and, moreover, it means the running to waste of the valuable manurial constituents of the sewage. The only practical means of disposing of these effluents is therefore to purify them by carrying them over land by irrigation, or, if land is not available, to pass them through specially constructed filter beds consisting of coke, or gravel, or of sand laid on magnetic oxide and carbide of iron. If the filtration be intermittent to allow of aeration of the filters the final effluent is usually sufficiently satisfactory to be allowed to pass into small rivers or streams.

Land Treatment.—The utilization of land as a medium for the purification and disposal of sewage has been accomplished in various ways. The sewage is passed on to the land either in its crude state or after some preliminary course of straining, or after clarification and precipitation of its grosser suspended matter by some form of chemical treatment. The application of sewage to land is conducted usually on one or other of two methods, namely, irrigation or intermittent downward filtration. If the sewage is discharged on to a piece of land, having in view a maximum growth of vegetation for the amount of sewage supplied, it is known as irrigation; if it is discharged upon land specially

prepared to receive it, making the crops or product therefrom of secondary importance, it is known as filtration.

In *irrigation* schemes, the soil must have a gentle slope and be drained by subsoil drains placed about 5 or 6 feet deep, by which the effluent can be conveyed to the nearest watercourse. To ensure success, the area must be sufficient and the sewage passed on at intervals, so as to permit of aeration of the soil. The land is laid out in ridges and furrows, and the sewage made to reach it in as fresh a state as possible, also freed from its coarser material by settlement or precipitation. Although sewage farms of this nature are not a commercial success, still immense crops of coarse grass can be obtained from them. Under favourable conditions, the purification of the sewage is excellent, the chief disturbing factors being frost and excessive rainfall. For dealing with sewage by this method, a large quantity of land is required—about 1 acre for the sewage of 100 persons, the area varying according to the porosity of the soil.

Land *filtration* of sewage may be upward or downward; the former is now practically abandoned as being totally inefficient. The process of filtration is essentially one of oxidation and nitrification, while intermittency of application is a *sine quâ non*, even in suitable soils; hence the process is commonly spoken of as intermittent downward filtration. The action of the land is also mechanical. As regards the soil itself, the physical conditions, porosity and fineness of division, have more to do with its cleansing power than its chemical composition. The best soil seems to be a loose marl, containing hydrated iron oxide and alumina.

The conditions necessary for the successful filtration of sewage through land are: (1) a porous soil; (2) an effluent drain not less than 6 feet from the surface; (3) proper fall of land to allow the sewage to spread over the whole land; and (4) division of filtering area into four parts, each part to receive the sewage for six hours, and to have an interval of eighteen hours. The quantity of land required is about 1 acre to purify the sewage of 1000 persons, and the larger solid bodies should be removed by straining before allowing the sewage to flow on to the land. When the amount of available land is limited, the sewage may be first treated by precipitation before allowing it to flow on the land, but this will deprive it of much of its manurial value. Preferably it may be passed through one or other kind of contact bed as described subsequently under biological methods. If the crude sewage be previously treated, one acre of land will suffice to receive the sewage of from 2000 to 5000 persons. Other than for small communities with suitable available land this method of disposal of sewage is not very generally adopted in the present day.

The effluent obtained is good after filtration of crude sewage through land, provided the details of the procedure have been carefully carried out, and is suitable for subsequent discharge into any river or stream. The solids tend to form a fine cake on the surface of the land, but these are readily broken up and worked into the soil. Generally all crops grow well on these sewage farms, but Italian rye grass and green vegetables do best. In Paris all kinds of vegetables and fruit trees are grown, and appear to thrive excellently under this treatment. When properly carried out, this is a valuable method for the purification and utilization of sewage, but it will be readily understood that, in view of the difficulty experienced in obtaining a sufficient area of suitable land, there are distinct limitations to its practicability.

Biological Methods.—Strictly speaking, the passage of sewage on to and through land is a biological method of treatment, inasmuch as it aims at, and more or less secures, a destruction of sewage as sewage, and a building up of new substances in its place by means of the organisms normally present in the sewage or in the land through which it is made to filter. Until recent years, land filtration was the only biological method of treating sewage available or practised. The difficulties associated with the securing of sufficient suitable land led to a closer study of the problem, and the development of new applications of the biological treatment of sewage has been a striking feature of recent sanitary effort. These new departures depend essentially upon bacteria contained in the sewage itself, and are based on the principle that organic changes in sewage are mainly due to bacterial action, and aim at fostering and assisting these changes by placing the sewage under the most favourable conditions for undergoing disintegration and oxidation by means of micro-organic life. Practically they are the direct antithesis of all methods of treating sewage by chemicals which, being for the most part antiseptic in action, modify and largely neutralize the vital action of the bacteria present in sewage. The micro-organisms existing normally in sewage may be said to consist broadly of two classes, namely, the "anaerobes" or those which exist without oxygen, and the "aerobes" or those to whom oxygen is essential. To those of the first group falls the main share of the work of breaking down, digesting, and liquefying the solid organic matter of sewage, whereby it is reduced to simple chemical states, chiefly ammonia; while on those of the second group devolves the duty and work of oxidizing, mineralizing, or nitrifying the ammoniacal substances into nitrites and nitrates.

The actual changes which take place in sewage, as the result of bacterial action, are somewhat complex and obscure, but they have been aptly described by Rideal as consisting mainly of three

stages. In the first stage, or that of anaerobic liquefaction and preparation by hydrolysis, the albuminous matters, cellulose, and fats are broken up into soluble nitrogenous compounds, fatty acids, phenol derivatives, gases, and ammonia. In the second stage, or that of semi-anaerobic disintegration of the intermediate dissolved bodies, a further formation of ammonia, nitrites, and gases takes place. In the third stage, or that of aeration and nitrification, ammonia and carbon residues are changed into water, carbon dioxide, and nitrates.

A large variety of installations have been devised to secure these really natural or biological changes in sewage; though they differ from each other in matters of detail, they all are the same in principle. The majority of the installations in present use embody the principle of dividing, more or less, the whole process of sewage purification into two stages; namely, a first stage identical with that referred to above, which is chiefly anaerobic and secures the liquefaction of the solids, and a second or aerobic process which embraces the second and third stages of Rideal and establishes nitrification of the previously unstable products. After a preliminary screening to remove paper and other coarse material from the sewage it is passed into a small detritus pit, to the bottom of which fall stones and other heavy adventitious matter; the first stage of the purification is then secured by passing the sewage into a septic or digesting tank of a size sufficient to hold 24 hours' flow of sewage. From this tank the sewage is then made to pass slowly into or on to one or more filter beds, in which aeration or nitrification takes place and so completes the second stage. The earlier types of septic tank were closed tanks, but experience showed that when sewage is allowed to flow slowly through an open tank, a thick spongy scum gradually covers the surface. This scum provides a cheap roof which preserves the heat in the sewage, promotes bacterial action, and tends to prevent the production of smell. Moreover, the action of these open tanks is just as efficient as the closed ones and are also cheaper to construct. The action of the septic or anaerobic tank leads to the digestion of some 40 per cent. of the suspended solids of sewage, with the result that the tank effluent rarely contains more than 20 parts per 100,000; also, the stability of the organic solids of the sewage is reduced rapidly by a short stay in a tank and subsequent purification much facilitated.

A typical installation is that suggested originally by Cameron of Exeter and shown in Fig. 53. In it the sewage first passes through a tank of about one day's sewage capacity, from which it overflows in accordance with the rate of flow of the sewage. Thus

it may be said all sewage is in the tank for 24 hours. Digestive changes take place in the sewage within this tank as the result of anaerobic bacterial action, which is favoured by the darkness, the absence of air, and the comparative stillness at which the sewage is maintained. Under these influences much of the solid matter is rendered soluble and dissolved. After passing thus slowly through the tank the more liquid portion of the sewage passes away in a thin stream along an open trough or aerator, over the edge of which it flows, and is ultimately discharged on to filter-beds. At this stage the sewage appears as merely dirty water, but having some offensive smell which is given off as the liquid passes over the filter-beds. The filter-beds consist of clinkers or coke breeze, in which the aerobic and nitrifying organisms attack the sewage constituents and complete the work of organic disintegration commenced in the septic tank. The sewage is passed on to the filters by means of an automatic gear, which allows them

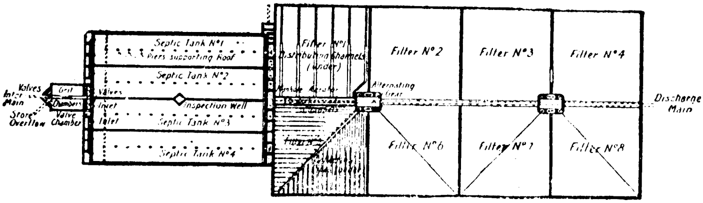

FIG. 53.—Plan of a septic tank with contact beds installation.

to be filled almost to their top surfaces and then to rest for a period of two hours. This is why these filters are called "contact beds," as it is during the period of contact with the material in the bed that the nitrification of the sewage takes place. After remaining quiescent for two hours, the sewage is slowly run off, the beds emptied and allowed to rest for several hours. Actually each filter-bed is filled up three times in twenty-four hours, and this necessitates the provision of several such filters in even small installations. The intermittent application of the sewage to the contact beds insures a certain amount of aeration of the beds.

Filtrates or effluents from installations of this kind are bright, clear, and stable. In the process the action of the anaerobic bacteria is encouraged in the septic tank and carefully differentiated from the subsequent aerobic action due to other organisms in the filters. The periodical resting and aerating of the filter-beds helps obviously to maintain the activity of the aerobic bacteria.

Many modifications of the septic tank system have been worked successfully all over the country, using an open septic

tank with double filtration through primary and secondary contact-beds, or even aerating beds on to which the clarified sewage is made to stream continuously by means of rotating sprinklers or other devices, such as troughs and elongated water wheels pivoted at the centre, or by travelling distributors. Aerating beds or streaming filters continuously dowsed with sewage are more expensive to construct and maintain than contact-beds, and are more often a nuisance from flies. No matter what may be the form or nature of a filter for sewage, it is necessary to realize that they differ essentially from water filters, in that the latter act as interceptors of micro-organisms, while the former act as a mesh-work of bacteria preying actively upon the sewage.

The most notable departure from the simple septic tank as originally conceived was Dibdin's subjection of the sewage to primary anaerobic action in an open contact-bed filled with very coarse material or rough ballast, in which the sewage remained for two hours. The results by this method have been good, but these rough primary contact-beds have the great disadvantage that the upper layers rapidly become choked or clogged and constantly require raking or ploughing to clean and aerate. From this primary or roughing bed the sewage is passed on to secondary contact-beds in which the matrix is of finer material. From installations of this modified type, the best results have been obtained when a greater area of coarse filter than of fine filter is provided, and that the sewage is locked up for four hours in the coarse beds and for two hours in the fine beds.

When the biological treatment of sewage was first introduced it was assumed that a relatively short stay in the digestive or septic tank would lead to a more or less complete solution of the suspended solids and a removal of the sludge difficulty. Prolonged experience has shown this to be far from the case, as the majority of digestive tanks and even filter-beds also lose in the course of a few months from 50 to 30 per cent. of their cubical capacity owing to the deposition of undigested solids. The recognition of this fact, particularly in the case of septic tanks, where the deposition of sludge is often considerable, has led to a variety of suggestions as to their size and construction. The most favourable size for these tanks is now held generally to be equal to one day's average flow of sewage, but in some successful installations it is found to be considerably more, or even much less. To avoid the undue washing over of this sludge and scum from the digesting tanks on to the filters, the introduction of scum-boards has been advantageous, but even in regard to this detail, absolute uniformity in method and result has not been secured. We find precisely the same state of

affairs in regard to the filter-beds. There is no unanimity of opinion as to whether the beds should be worked on the contact, that is, intermittent, or the continuous system; whether there should be single, double, or even triple contact-beds; of what size and material the filtering material should be, or how the sewage should be best delivered on to the filters. On each and all of these points there is much divided opinion, the truth being that there is no hard-and-fast rule, and that each class of sewage must be dealt with according to its conditions. Multiple filters are needed where strong or alternating weak and strong sewages have to be dealt with, because a filter or contact-bed will effect only a certain percentage reduction of the foul ingredients of the sewage it receives, even when it has reached its maximum ripeness or biological efficiency. It must be remembered that in these cases we are dealing not merely with the reduction of unstable material to ultimate products but the reduction of the more stable organic matter to the unstable condition. This latter is best effected by rest in a contact-bed or filter, and the former by passage from one filter to another. There is a general agreement that the best working depth for a filter-bed is from 4 to 8 feet, and that the 8 hours cycle of treatment of these contact- or filter-beds gives the most consistent results, that is, 1 hour to fill, 2 hours to rest full, 1 hour to empty, and 4 hours to rest empty. If this cycle be maintained, the various types of contact-beds can be worked at the rate of a million gallons per acre per diem.

The difficulties arising from the often offensive effluent from septic tanks, or even primary roughing contact-beds, led Dibdin to advocate the preliminary treatment of crude sewage in tanks or contact-beds in which the refuse of slate quarries laid in close layers some 2½ inches apart and supported on suitable slate blocks furnished the necessary matrix in a tank about 4 feet deep. In such an installation the crude sewage is best sedimented in detritus tanks before passing to the slate bed, and if the effluent from this latter contains much suspended matter it should be made to pass through a shallow humus bed to deposit the fine sediment before it is distributed to contact-beds or to aerating continuous filters. The effective working of this slate type of contact-bed appears to be a cycle of 1 hour filling, 2 hours contact or holding up, and from 6 to 12 hours for emptying and aeration, according to the strength of the sewage. Experience shows that there is no necessity in ordinary cases to wash out the deposited solids, but that as they become digested by the organisms, the resulting product resembling earthy matter gradually passes away with the liquid. The great advantage of

the slate beds in a satisfactory installation is that the primary effluent is inoffensive and much less liable to create a nuisance on secondary treament than is the septic effluent from a septic tank, or even a coarse roughing primary contact-bed made of rough ballast.

Recently, the employment of what is called "activated sludge" has been tried in sewage purification. The method is one by which finely divided air is forced through sewage in specially constructed tanks. The sludge is allowed to settle, the supernatant fluid run off, and the tank again filled with sewage and the aeration process repeated. The essence of the method is that the sludge which accumulates acquires by degrees, under aeration, the same properties as the slime which forms upon the upper layers of a filter-bed, and, when fully matured, this activated sludge, if mixed in the proportion of one volume to from three to five volumes of sewage in a tank by blowing air through the mixture for a period of from two to six hours and then allowing the clotted mixture to settle, yields a clear and stable supernatant liquid or effluent equal in stability and inoffensiveness to that obtained by other methods. We have no personal experience of this method, but excellent results are reported to have been obtained both as to quantity of sewage treated and the degree of purification effected.

In all sewage installations on the biological principle certain difficulties arise when certain trade effluents, especially acids and brewery or tannery effluents, are passed into town sewage. These materially upset the action of the essential micro-organisms concerned in biological installations. The only remedy is to submit these objectionable trade by-products to dilution or preliminary treatment by lime before they are permitted to leave the premises on which they are produced. The same remark applies to trade effluents rich in fats or soapy matters. These need to be passed through suitably constructed grease traps or treated with acid or lime or aluminoferric. Another factor which needs attention in *all* sewage purification installations is the question of capacity and volume of sewage to be treated. The rule is that storm water amounting to three times the dry weather flow of sewage must be treated as sewage, and that any additional volume of storm water up to six times the dry weather flow must receive treatment either by means of an artificial filter or by passage on to land used for no other purpose. Special filters of burnt ballast will usually deal satisfactorily with 500 gallons of dilute sewage to each superficial yard of filter area, or about 2½ million gallons per acre per diem. In all sewage installations, therefore, the local authority must make provision for treatment of six times the dry weather flow.

Comparison of Different Methods.—We cannot dogmatise as to individual systems. The requirements of the sewage of each and every place must be determined by local circumstances and no hard and fast rules can be laid down as to whether a system of contact-beds or a continuous filter installation is the better. A much greater volume can be treated per square yard by sprinklers than on contact-beds. Unsedimented sewage should never be passed on to the percolating or sprinkling filters, as the distributing arms speedily choke and a colloidal matted growth forms on the surface of the bed, which impedes aeration. Strong-smelling or putrefactive sewage should not be treated by revolving distributors or fixed sprays, as the odour is intensified by this mode of distribution. As regards matrix for filter-beds, favourable reports are made as to ligno-carbon, a manufactured product from peat, otherwise hard clinker from gasworks or from refuse destructors for primary filters, and coke or pan breeze for secondary filters appear to be the most suitable and readily obtained material. If the sewage is free from manufacturing effluents of injurious character, and if a sufficient area of suitable land can be obtained in a convenient position at a reasonable cost, then irrigation is probably the most rational and economical method of treatment. Many kinds of manufacturing refuse, if admitted into sewers, interfere with the efficacy of land filtration, either by clogging the soil or checking chemically the process of oxidation; this latter condition operates prejudicially also in biological methods. In these cases, a preliminary purification by precipitation is necessary, and it is probable that different forms of chemical treatment will be found necessary for effluents of different trades.

In all cases, the principle to be aimed at is the immediate and complete removal of all kinds of refuse from the vicinity of habitations in the most expeditious manner. The dry methods do not answer this requirement, as the excreta is only removed at intervals, and although deodorization may be complete, disinfection is not attempted. For a large population, therefore, some system of water carriage is necessary. Having, therefore, sewage to deal with, we must get rid of it in the least objectionable manner. It must not be sent into rivers; therefore, where land is available, immediate application to the land, by irrigation or filtration, is indicated. By land filtration, sewage can be purified so that the effluent water may be permitted to run into any stream or river, the water of which is not required for drinking purposes. Little, however, of the manurial value is saved, the greater part passing away in the effluent. Irrigation accomplishes all that is done by filtration, with the further advantage that the whole of

the manurial constituents of the sewage are returned to the soil, which is fertilized by them. Both systems are, however, often impracticable owing to lack of suitable land.

As regards the biological treatment of sewage, it can now be stated definitely that the average results are as good as those given by well-managed sewage farms, while the best results are a long way better than those recorded of any sewage farm. A most important feature in the biological treatment of sewage as compared with any chemical process is that, when properly carried out, it yields an effluent which is incapable of secondary putrefaction. In this respect it may be regarded as the best solution of the sewage problem, because the stability of an effluent which has been mineralized by a biological process is absolutely secure. We feel convinced that biological methods of treating sewage are not only scientifically correct, but sufficiently efficient and economical in their working as to quite preclude any reversion to artificial methods, such as treatment by chemicals or electricity. In formulating this opinion, we would emphasize the paramount need of the biological treatment of sewage being carried out logically and scientifically, and with due regard to the fundamental principle that it needs to be conducted in stages; these are, (*a*) settlement and screening out of the grosser solids; (*b*) the submission of the organic sewage matter to the action of both anaerobic and aerobic micro-organisms under such conditions that the maximum action of both groups of micro-organisms is secured. The optimum conditions for the attainment of this maximum action appear to be available by the suitable use of either closed or open septic tanks, or rough primary contact-beds, or slate beds followed by aeration either in secondary contact-beds, or by continuous streaming over suitably constructed aerated filters. The factor which governs the bacterial population of a sewage filter-bed is the area available for growth, and this may be increased either by enlarging the cubic capacity of the filter or by subdividing the filtering medium. Therefore, we may make this generalization that, whether it be for a contact-bed or for a continuous filter, the finer the matrix the less need be its depth, and *vice versa;* to this we may add, as the outcome of experience, that primary contact-beds need to be made of coarser material than secondary or tertiary beds. As affecting the successful working of any sewage filter-bed, it is necessary that the bed should be worked very slowly at first, in order to allow it to settle down and the bacterial growths to form. In this way there will be less danger of suspended matter finding its way into the body of the bed, while the material is still loose and open. The work thrown on the bed should not be increased until analysis of the

effluent reveals the presence of surplus oxygen, either dissolved or in the form of nitrates. Analysis of the air in the bed may be made usefully from time to time during resting periods. The variations in capacity should be recorded carefully. If the capacity is found to be decreasing rapidly, a period of rest should be allowed. Long periods of rest should be avoided during winter, as when deprived of the heat of the sewage the activity of the organisms decreases. If necessary, the burden on the bed should then be decreased by reducing the volume of sewage applied daily, rather than by exaggerating any intermittency of working. What form installations for sewage treatment will take ultimately it is difficult to say but, doubtless, further developments in the biological treatment of sewage will occur. These probably will assume the form of a greater and more exact control, not only of anaerobic, but also of aerobic action. In other words, we shall be able to establish standards for treating sewage in anaerobic beds or tanks for a definite time, and subsequently treating it in aerobic beds containing particles of definite size, and the flow of both sewage and air being so controlled and regulated as to pass through the installation in definite quantities. Exact work in these directions is greatly needed as, at present, even the most successful installations are empirical.

Sewage Effluent Standards.—Though modern methods are great advances in the treatment of sewage, especially in destroying and rendering the organic matter soluble, the resulting effluents are teeming with microbial life—in fact, in this sense, are little different from the original sewage. Moreover, we know that specific and pathogenic bacteria do survive passage through these installations, and can find their way into the resulting effluents. From these facts, it is evident that there are very grave risks where sewage effluents are discharged into streams used for water supply, or into water where water-cress is grown, or into estuaries where oysters are laid. No general standard applicable to all cases is possible or desirable. The best possible results must be sought, having due regard to the nature of the sewage, and to the conditions, volume, and uses of the stream which is ultimately to receive it. Certainly no effluent from a biological sewage installation should be allowed to pass direct into any stream or river. It should be made to pass through land before it reaches the stream. The effect of an effluent upon a stream depends less upon the absolute amount than on the nature and condition of the organic matter contained in it. If an effluent is non-putrescible on incubation its organic matter must have undergone a satisfactory amount of fermentation, and consequently will remain

stable when discharged into a stream, and will take up little dissolved oxygen from the water into which it is discharged. Such an effluent will not create a nuisance and will not injure fish life.

There being no satisfactory bacterial tests which can be applied to a sewage effluent, it is customary to regard the following conditions as the absolute minimum to be demanded of an effluent before it can be regarded as satisfactory. It must be clear, bright, and free from any odour of sulphuretted hydrogen, it must not contain more than 3 parts of suspended matter per 100,000, and show no physical signs of putrefaction after incubation for a week in a closed vessel at 80° F. Formerly, some importance was attached to the amounts of free ammonia, organic or albuminoid ammonia, and chlorine as chlorides in a sewage effluent. In the present day, these constituents are regarded as of secondary importance and greater attention directed to its capacity to absorb dissolved oxygen, the test to be applied to the effluent with all its suspended solids. The absorption of dissolved oxygen should be allowed to proceed for five days at a uniform temperature of 65° F., and in this period the absorption of dissolved oxygen should not exceed 2 parts of weight per 100,000 parts of effluent, this is equivalent to 14 c.c. per litre. Further, the effluent should not contain more than 3 parts of suspended solids per 100,000. In testing the condition of a stream which has received a sewage effluent, the following provisional standards are practicable. Since the average amount of oxygen found in clean fresh water saturated with this gas is 7 c.c. per litre, or 1 part per 100,000, then a stream which has received a sewage effluent may be considered to be very clean if no more than 0·1 part of dissolved oxygen be taken up by 100,000 parts of the water from the stream after incubation at 18° C. or 65° F., for five days. If 0·2 part be absorbed then it may be classed as clean, if 0·3 part then fairly clean, if 0·5 part it is doubtful, and if it absorbs 1 part per 100,000 then such stream is bad. On the basis of this scale, if a river which has received a sewage effluent does not take up more than 0·4 part of oxygen per 100,000 in five days at 65° F. or 18° C., the water will be ordinarily free from signs of pollution; but if the absorbed dissolved oxygen be above this figure, signs of pollution will almost certainly be apparent coupled with a strong probability of nuisance arising.

Camp Sanitation.—The number of camps and temporary lodgments which have been distributed over the country in recent years demand some appreciation on the part of the ordinary citizen as to their general sanitary control. In principle, the sanitation of a camp is the same as that which concerns a

group of ordinary dwellings; it differs therefrom mainly in the circumstance that its actual practice is essentially the use of simple methods and simple material used in an intelligent way.

All camps may be regarded as so many improvised towns, in which the tents and huts represent so many houses. The selection of a camp site is dominated largely by the facilities which exist for obtaining water; this is more particularly so in regard to temporary camps, but where camp sites are likely to be occupied any length of time the feasibility of bringing water to the camp must be considered as much as taking the camp to the water. Apart from the question of the water supply, the selection of a camp site differs little from the selection of a site for an ordinary house or group of houses. The only points which are more particularly exaggerated are the need for a porous soil and physical features favourable for rapid and easy surface drainage; in other words, choose areas which are not only dry but clean, that is, have not been occupied recently for other encampments, and are not fouled or in any way encumbered with the recent filth of man and animals.

Although in army life, certain regulations exist as to the manner and place of laying out various camps, it will be readily understood that these are subject to constant variation, owing to physical difficulties connected with the locality. These restrictions play a less dominant rôle in many camps of a *quasi* military nature, or under circumstances where freedom of choice exists as to siting and lay out. In camps composed exclusively of tents, the chief danger lies in overcrowding in the tents. Due regard is paid to this as much as possible, but often circumstances compel the placing of the full complement of men in various types of tent, with the result that the superficial space available for each individual may be as little as 11 and rarely more than 20 sq. feet. In camps of a more permanent nature, especially where huts are available, the danger from overcrowding is more under control and the floor space is never less than 50 sq. feet per man, with a cubic space of 500 feet per man. It is a good rule, never to put more than 8 or 10 men in a bell tent and not more than 24 men in a hut.

Where tents are in use, the tent walls must be looped up daily so long as the weather permits, so that the tent area may be dried and freshened by air and sunlight. Even in cold and doubtful weather the sides of tents should be tied up during the absence of the occupants. All tents should be struck and their enclosed ground area aired or sunned for a few hours every five days. In a properly arranged camp, the intervals should be sufficient to render the shifting of a tent to a new site possible. Where huts

are used, the doors and windows must be opened daily to permit of aeration and the entrance of sunlight. The digging up or excavating out of the soil within a tent area is unwise as impeding cleanliness and ventilation; if floor-boards are not available, then the ground may be covered with either straw or a tarpaulin; but whatever is employed it must be turned out, aired and cleaned daily. Blankets, bedding, and clothing must be sunned and aired each day either by hanging on improvised supports erected specially for the purpose, or by spreading on the sunny side of the tent roof; the former plan is preferable, as it allows access of light and air to both sides of the article.

On no account should men be encouraged or allowed to store food in their tents or huts. If food must be retained by the individual, every endeavour must be made to keep it in closed tins or boxes so that neither flies nor dust may gain access to it. All food remains, particularly if not likely to be utilized in a few hours, should be either burnt or buried. Similarly, occupants of camps should not eat their meals in the same tents or huts which they use for sleeping or general shelter. Sometimes it is impossible to arrange otherwise, especially in temporary or hastily formed encampments, but in all well planned and well managed permanent encampments one or more marquees or huts are set aside and used only as dining-rooms.

In camps of a permanent nature, arrangements are made usually to bring the water supply by a pipe service into the camp area and deliver from stand-pipes. Where this is the case, no sanitary difficulties arise as a rule, except the risk that the very facility with which water is available may lead to waste and the soddening of large patches of ground around the delivery taps. The exercise of common sense and initiative should remedy this trouble, mainly by providing suitable surface drains to carry off such wasted water or by penalizing the camp occupants to furnish so many men daily to act as picquets or sanitary guards over each stand-pipe. Such stand-pipes should be adjacent to kitchens and ablution places but remote from urinals and latrines, unless, of course, a water carriage system of sewage disposal has been installed. This latter arrangement is, however, rare. Where local water is the source of supply, care is needed to safeguard its pollution by the camp occupants and to avoid waste. Men and animals should not take their drinking water from the same place on the banks of streams, the animals must invariably be watered at a point down the current below that at which the men's water is drawn. In camps dependent on a local source, the water is carried usually from its source to the lines in tanks on wheels or even by smaller vessels. In all cases, care is required

to keep these receptacles clean, and where water is kept stored in camp the tanks, barrels, or other vessels must be protected from dust and other contamination by suitable covers. Men should not be allowed to drink direct from the taps of stand-pipes or of water-tanks, or from the rims and spouts of other receptacles used for carrying and distributing water.

The cooking of food in camps presents no serious sanitary problems; at best it must be rough and crude. The most important details which need attention are: (1) that the kitchens be located well away from latrines, urine pits, or other receptacles for refuse and garbage; (2) all sullage water must be made to pass into pits from which it can drain away along suitably dry trenches. This waste water is greasy, and if allowed to pass direct on to the soil soon makes a greasy quagmire covered with a scum which attracts flies. Sometimes such sullage water may be poured into specially placed tubs which are carted away periodically. If these are in use, they must be kept covered and removed daily. Where disposal of this greasy waste water depends on local absorption by the soil, a useful plan is to fill the reception pits or preferably the upper ends of the drainage channels with hay, straw or coarse brushwood; if the greasy water be poured slowly through these coarse strainers the grease and other organic solids are entangled, allowing the clearer liquid to run away. The brushwood, straw, or hay, loaded with fatty matter, must be buried, or better still burnt, daily and replaced by fresh material. The soakage pits need watching so that they are not overworked. It is usual to make a series and use them in turn for definite periods according to the nature of the soil and the volume of greasy water to be removed. Closely associated with the kitchens and food supply is the system available for washing up cooking utensils, plates and dishes. These details are often overlooked. For all camps, a particular and separate washing-up place should be allocated. This and the kitchen should be situated conveniently close to the tent or hut in which meals are eaten, also provided with an ample supply of hot water and a sufficiency of dish cloths to secure always a clean and wholesome food service. No men who have suffered from enteric or paratyphoid fever should be employed as cooks or in the service of food; such men as are so employed should have been inoculated against enteric fever. The ablution places must be provided with adequate surface drains, otherwise they rapidly become sloppy, wet and dirty. Basins should be available at a rate of 14 per cent. of men using the ablution place and in addition bathing tubs for men wishing to have a bath should be available at the rate of 4 per cent. of strength. Whether a sufficiency of hot water can be made available will depend on

circumstances, but in permanent camps there are no insuperable difficulties in the way of its provision.

Kitchen refuse and the hundred and one things which go to make up the ordinary refuse from camps must never be thrown on the ground but always into special receptacles placed conveniently for the purpose, such receptacles should be provided with covers. Final disposal may be arranged for through a contractor, who deals with it at his own cost and risk, or it may be buried in deep pits or burnt. This latter method is the best and by means of simple improvised incinerators made of bricks, stones, or grass sods, arranged with plenty of access of air from below, the disposal of this material by fire is not difficult. The process is helped if the solid and liquid refuse be kept separate. The place chosen for these incinerators should be outside the tent or hut area.

The disposal of urine and excreta in camps is vital to the sanitary interests of all, but if ordinary intelligence be exercised it presents fewer difficulties than might be expected. In permanent camps provided with a piped water supply, a complete water carriage system of sewage disposal is the best, and in its general design differs little from that explained as appropriate for houses and other permanent buildings. When no such elaborate arrangements can be made, reliance must be placed upon either a trench system or a modified pail-midden system. Latrines, irrespective of method or kind, must be located well away from kitchens and preferably 100 yards from the outer limit of the tent or hut area. For ordinary or more or less temporary camps the usual latrine is a trench or series of trenches, provided or not with a seat. A latrine trench 20 ft. long, 2 ft. deep, and 1 ft. wide is the common allowance for each hundred men. These long trenches are difficult to provide with a seat, unless boxed over. A more preferable arrangement is to dig a series of short trenches in parallel, across which the user straddles. Each such trench should be 3 ft. long, 2 ft. deep and 1 ft. wide. Four of these trenches suffice for each hundred men. A seat in the form of a stout pole can be laid at right angles to the trenches, supported on forked uprights. A back rest may be formed by a similar pole, but is often omitted. The trenches in use must be surrounded by some form of screen, also covered with a roof if possible, and the earth dug out from the trenches well broken up and carefully piled either at the back or at the side of the trench. All displaced grass sods must be carefully stacked near by so that when the trench is filled in these grass sods can be replaced and the fouled area made neat and wholesome. Two or more spades or shovels or trowels must be available within the screen and with these each

user covers his dejecta with a sufficiency of earth. Kicking the soil in by the foot is certain to be a failure. Men must be made to understand the necessity for covering their dejecta before leaving the latrine. Failure to conform to this practice should be made a matter of discipline. Each day the latrine trenches should be filled in with earth, the whole pressed down and grass sods replaced. New trenches will then be taken into use. Should the latrine area be on a slope, it must be guarded on the upper side by a shallow drain to carry off surface water and so safeguard the trench contents being flooded out.

In some camps of a semi-permanent nature, it is better to provide pail-middens placed under boxed seats and providing a sufficiency of dry earth with scoops to enable each user to cover his own fæcal deposit. The disposal of the contents of these midden pails is best carried out by burning in some simple form of incinerator. Such an incinerator should be placed close to the latrine, and if the dejecta be mixed with sawdust, shavings, or dry camp refuse it can be burnt readily. Failing destruction by fire, the pail contents must be dealt with as in towns by hand and cart removal for disposal on land. Water-closet or latrine seats in camps need to be provided at rate of 6 per hundred men. Urinals consist either of a pit or trench filled in when used sufficiently, or special metal tubs are provided and the contents removed by hand or cart and disposed of either into soakage pits or poured on to land. Wherever possible, a water carriage system of excreta disposal should be adopted in camps. It entails no handling and no cartage of foul material, is largely automatic in action, and reduces to a minimum the risks of infection by soiled boots and flies.

CHAPTER VI.

PERSONAL HYGIENE.

By the term Personal Hygiene is meant the consideration of those matters which concern the person's own health, and which relate only to the individual himself or herself. It includes the discussion of such subjects as Habits, Washing and Bathing, Clothing, and Exercise.

HABITS.

Our habits may be either important aids to the promotion of health and the lengthening of life, or they may be important predisposing causes of disease.

Eating and Drinking.—It is of the greatest importance that all young people be taught to chew their food carefully and to eat slowly, as quick eaters generally suffer from indigestion later on in life. The excessive use of condiments and spices is a habit not to be encouraged. In youth we may eat plentifully, but in old age we should eat sparingly. The evils of intemperate habits and excess in alcoholic drinks are incalculable. Alcohol, besides rendering man's capabilities for work less, deadens the activity of the mind, interferes with the oxidation of waste matters in the blood, and so alters the character and function of the internal organs, particularly the liver and kidneys, that disease and death therefrom are, in most cases, the early result for those who habitually take alcohol in excess.

Smoking is another doubtful habit, and one for which there is not the slightest reason or excuse under twenty-one years of age. For elderly persons, or those in middle life, particularly when engaged in much mental or other work, the use of tobacco often soothes the mind and otherwise acts sufficiently as a restorative to the exhausted or fatigued nervous system as to justify the continuance of the practice.

Sleep.—The habit of taking sleep regularly is essential to health, for both body and mind need periodical rest, and it is only during sleep that this is obtained. Children need more sleep than grown-up people ; small children should sleep at least twelve hours a day, young lads and girls about nine hours, and adults about seven hours in a day. Night is the natural time for sleep. If possible, all people should sleep upon beds and bedsteads ; to sleep upon the floor and ground is frequently unhealthy. Plenty of fresh air is wanted at night and during sleep ; hence people should not sleep with the head covered up, neither should they lie in draughts and cold currents of air ; the body needs to be kept warm at night to avoid chills. All bedding should be kept clean and fresh, as waste matters from the body stick to them and, if allowed to remain dirty, give rise to ill health.

The regular removal of waste substances from the body is most necessary for the preservation of health ; for if they are not removed, they become re-absorbed into the blood, and there act as poisons. Since the organs by which waste matters are removed from the body are the lungs, the skin, the kidneys, and intestines, it is important that all should early acquire habits suitable for

keeping them in proper action. The chief agents in regulating the action of the first three are cleanliness and exercise; with regard to the last, the formation of a regular habit early in life is essential, while exercise also helps the action of the intestinal canal.

Another good and important habit is that of cleansing the teeth; this should be done at least twice a day; such a practice, besides keeping the mouth clean and sweet, helps to preserve the teeth themselves, and prevent their decay. For those teeth which are decayed, much can be done by going to the dentist, and having the decayed parts cleaned out and "stopped," or plugged, so as to avoid any further extension of the decaying process.

Washing and Bathing.

If the skin is not kept thoroughly clean, the dead scales of it, which ought to be removed, collect upon the surface and, with dirt, block up and check the proper action of the many glands contained in the skin. If the skin does not do its work properly, more has to be done by the lungs and kidneys; and these, if they have too much to do, are likely to get diseased from over-work. The free use of water is an excellent stimulant and tonic to the skin; but to remove dirt and grease and for purposes of cleanliness, bathing or washing without the use of soap and friction is useless.

Soap is either a potassium or sodium salt of one of the fatty acids, stearic, oleic, palmitic acid, etc., produced by the action of either potash or soda upon the fats. Potash soaps are very deliquescent, retaining so much water as to form often a soft jelly: of this kind is *soft soap*. Soda soap retains little water, and readily hardens when exposed to the air, constituting hard soap. Ordinary soft soap is largely made from whale or seal oil, and the drying vegetable oils, such as linseed oil. Ordinary hard soaps are commonly made from tallow and the non-drying vegetable fats and oils, their hardness being in proportion to the stearic and palmitic acid which they contain. *Marine soap*, or soap used for washing in sea-water, is made by the action of potash or soda upon cocoanut oil.

Yellow soap is made by a mixture of resin with tallow and palm oil, or with a grease stock consisting of kitchen and bone fat. It is very firm, somewhat rough, and often translucent. *Toilet soaps* are varied in quality. They are commonly made from lard, beef marrow, or sweet almond oil, and after repeated refinings by melting and powdering, finally scented with some perfume, such as the oil of roses, bergamot, mallow, lavender, verbena, rosemary, thyme, etc. Their colouring depends upon special pigments added to them. What is called Brown Windsor is an inferior

soap of this kind, being made from the residue of
scented with nitro-benzene or artificial oil of bitter alm
Glycerine soap is merely ordinary soap, to which glyc
been added. The transparent soaps are made by drying
soap in a stove, and then dissolving it in hot alcohol; subseq
this solution is filtered, the alcohol distilled off, and the re
run into moulds. *Silicated soaps* are ordinary soaps mixed
solutions of soluble glass or silicate of soda. These mixed soaps
have exceptional cleaning properties, owing to the quantity of free alkali which they contain. Some of the so-called silicated soaps are mere mechanical mixtures of silicious substances, such as fine sand or fullers' earth, with ordinary soap; these are comparatively worthless.

Baths.—Water being a very much better conductor of heat than air, it rapidly abstracts heat from the body if much below the temperature of the latter, which is roughly 98° F. Owing to their physiological action being mainly dependent upon their temperature, the following classification of baths has been made:—

1. Those in which a healthy person feels neither hot nor cold; these are often called indifferent baths. Their temperature varies from 88° to 98° F. Some indifferent baths may be called warm baths, while those intermediate between warm and cold are often spoken of as tepid baths.

2. Cold baths, or those in which a healthy person feels cold. Their temperature varies from 32° to 60° F. If the bath is only moderately long and not very cold, the body heat remains constant, because the production of heat balances the loss. If much prolonged, there is an actual loss of body warmth. Cold baths greatly increase the tissue waste of the body.

3. Warm baths, or those in which a healthy person feels warm. Their temperature may vary from 100° to 103° F. A warm bath increases the body heat by both imparting warmth to it and preventing loss of heat from it. Some people, particularly the Japanese, use very hot baths indeed. Unless one has been gradually educated up to them, exceptionally hot baths should not be employed. Vapour and Turkish baths are varieties of the warm bath. The latter is practically the passing of a longer or shorter time in rooms at temperatures rising from 100° to 200° F.; during this period, the action of the skin is vigorously encouraged, and the body, after cleansing with soap and friction, gradually hardened by sprayings of water passing from hot to cold, followed by a cold plunge and subsequent rest or detention in a cool room.

A short bath is usually followed by a sense of well being, due to the increased activity of and removal of waste products by the

keeping the ans, consequent on the contraction of the superficial or action of blood-vessels. The feeling of warmth, which so com- to the la sues, and ought always to ensue, after leaving a cold bath, while e ably to be explained by a reactionary dilatation of the Ar s of the skin after their original contraction. If a bath has teeth too prolonged, or the person be at all enfeebled, there may be no subsequent feeling of warmth after bathing. All bathers, therefore, should take care not to in any way prevent the reactionary dilatation of the superficial or cutaneous vessels, by either remaining in a bath too long or using it at too low a temperature.

Cold baths, if not too cold, are particularly enjoyable, on account of the reactionary exhilaration which follows. Their regular employment is specially favourable for training the capillaries to alternately contract and dilate, and thereby render habitual bathers remarkably free from liability to catch cold.

It is a mistake to bathe either fasting or immediately after taking a full meal; and equally injudicious to do so when exhausted by fatigue. The best time for a bath is either early in the morning after a cup of tea or coffee and a biscuit, or an hour or so after breakfast. Persons advanced in years, and those in whom the circulation is weak, should neither attempt outdoor bathing nor indulge in very cold baths at home; in them the resisting and rallying powers are often low, and reaction correspondingly difficult to secure. A very hot bath, of 100° to 110° F., is often less depressing than a warm one of a lower temperature, as it stimulates both the skin and circulation. To avoid chills, such very hot baths are best taken at night. The following table indicates the approximate temperatures of water-baths, arranged according to popular designations:—

Very cold	32°	to	50°F.
Cold	51°	,,	60°.
Fresh	61°	,,	75°.
Tepid	76°	,,	88°.
Warm	89°	,,	99°.
Very warm to hot	100°	,,	110°.

It must be remembered that no very precise division of baths can be made, as no two persons are equally sensitive to the effects of heat and cold.

Clothing.

The main objects of clothing are: (1) to protect the body from cold, heat, wind, and rain; (2) to maintain its warmth, protect it from injury, and also to adorn it. The chief materials

used for clothing are derived from animals and vegetables. From the animal world we get wool, fur, leather, feathers, and silk; while from vegetable life we draw cotton, flax, jute, hemp, coir, indiarubber, and guttapercha.

Wool is a modified form of hair obtained from sheep, goats, camels, and other animals. Wool fibres (Fig. 54) have on their surface fine imbricated scales, which run in one direction, and give it a serrated or toothed appearance when

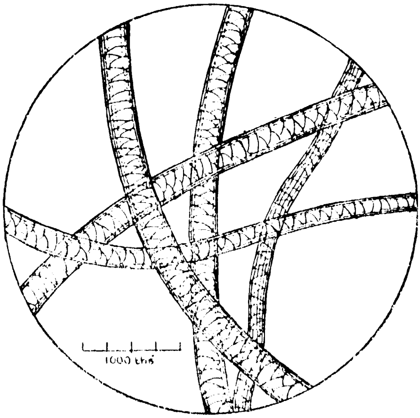

FIG. 54.—Wool under the microscope, taken from white flannel.

examined under the microscope. Wool is soluble in caustic alkalies, while vegetable fibres are not so. The wool from the Angora goat is known as mohair, and is largely used in the making of plushes, velvets, astrachans, and other fancy fabrics. Alpaca comes from the Peruvian sheep, a kind of llama. It is a very fine silky wool, and greatly used for shawls and umbrellas. Cashmere is a specially soft and fine wool from the Thibet goat; it is very expensive and difficult to get. Camel's hair is really a fine wool; it is now chiefly met with in the underclothing of Jaeger. Wool is largely used for the making of flannel, cloth, blankets, worsteds, and knitted goods. Felt is really wool made up without either weaving or spinning, the whole holding together simply by the cohesion of the serrated fibres.

Wool is the best material for underclothing; it conducts heat badly, and while absorbing moisture readily, gives it off slowly, so that far less cooling is produced by evaporation from the woollen garment than from any other. It has the disadvantage of hardening and shrinking on washing.

Furs.—These are the skins of certain animals from cold

countries, which have, in addition to their long "overhair," a dense hairy covering called fur. The chief are bear, seal, chinchilla, ermine, and Russian sable or marten. Fur is often used for making felt; hat felts are chiefly made by compression under heat and moisture of the fur from horses and rabbits. The coarser felts used for carpets are made from cow-hair.

Leather.—The skins of animals, if appropriately prepared by tanning, tawing, or shammoying, are rendered tough, yet soft and fit for use by man as clothing. The chief skins so used are those of the ox, sheep, horse, and goat. *Tanning* is the steeping of a skin in an infusion of oak bark or other substances rich in tannic acid. By this process, insoluble tannates of the gelatin and albumin of the hides are formed. To be properly carried out, tanning takes nearly a year. *Tawing* is the same process as tanning, except that mineral astringents such as alum and bichromate of potash are used in place of the vegetable product, tannic acid. Tawing is more rapid, but yields an inferior and harsher leather than tanning. *Shammoying* is the impregnating of a skin with fish oil; it is chiefly applied to light skins, and is the process by which chamois leather is prepared.

Feathers are not much used for actual clothing, but rather as ornaments. Their employment is still considerable for stuffing pillows and beds. These latter, if not made too soft and luxurious, are quite as healthy as any other bed.

Silk.—This is the strong fibre produced or spun by the caterpillar or larval stage of certain moths. The silk threads are formed in two small glands situated on the under part of the body and opening by a duct on the lower lip; the silk serves as a protecting sheath or covering, called a cocoon, for the silkworm when about to assume the chrysalis stage. The silk thread so ejected by each worm and wound into a cocoon, measures some 4000 yards in length and consists of two fine filaments, one from each gland, laid side by side and agglutinated together into a single thread or fibre. The best silk is produced by the larva of the moth called *Bombyx mori*, or Chinese silk-moth. Other kinds of silk are spun from other silkworms closely allied to the *B. mori*. There are the *B. textor* and *B. fortunatus*, common in Bengal; the *B. crœsi*, found in Madras; the *B. arracanensis*, met with in Burmah; and the *B. sinensis*, belonging to China. All these are mulberry feeders. The caterpillar of another moth called *Antherœa pernyi*, found in Mongolia, and which feeds on oak leaves, spins the kind of silk known as tussur silk. The *A. mylitta* is another variety of the tussur silk-moth, common in India. It feeds on bher trees and other shrubs. Similar moths are found in Assam and Japan.

The silk fibre (Fig. 55) consists of a central core or fibre, covered with a waxy and albuminous colouring matter. Microscopically, silk fibres are structureless and glass-like, usually measuring some $\frac{1}{2000}$ inch thick, and without surface markings or scales. Silk is insoluble in water, alcohol, and ether, but dissolves in very strong alkalies, mineral acids, and acetic acid. It is readily distinguished from wool or other animal fibre by the action of an alkaline solution of lead oxide, which, owing to the presence of sulphur in wood, darkens it, but does not affect silk. Silk is distinguishable from vegetable fibres by being stained yellow by picric acid, which they are not. The average cocoon yields some 500 yards of workable silk, which in its manufactured form is either reeled or spun silk—this latter being prepared by carding or spinning from the waste and spoiled cocoons. During its manufacture into fabrics, silk fibre is largely altered, expanded, weighted, and dyed by various reagents, notably salts of tin and iron, which render the term "silk," as applied to actual articles of clothing, a more or less conventional expression of what something is meant and ought to be. Silk is mainly used in the manufacture of satins, silks, plushes, velvets, ribbons, crape, and in a few woollen goods to give them lustre. Silk is very absorbent of moisture, and is a non-conductor of electricity.

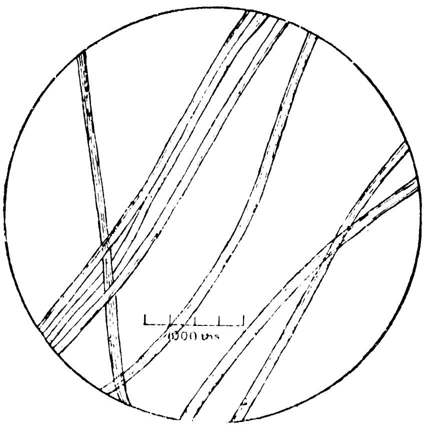

Fig. 55 —Silk from a silk thread.

Cotton is the downy hair of the seeds of plants belonging to the family *Gossypium*, of the order *Malvaceæ*. The cotton fibres consist mainly of cellulose, and vary from a half to one inch in length. The fibres are freed from the seeds by machinery, and, after being cleaned and spun into yarn, are woven into fabrics, which, after being bleached, are "finished" for the market. This finishing process usually involves mangling, starching, and damping, and often includes filling up the interstices between the fibres with compounds to give weight and a false appearance. Cotton is largely made up into sheeting, calico, towelling, jean, fustian, velveteen, flannelette, and paper. When mixed with wool, it

constitutes the merino of vests, socks, and many fancy materials; it is also mixed with silk or the cheaper kinds of silken goods.

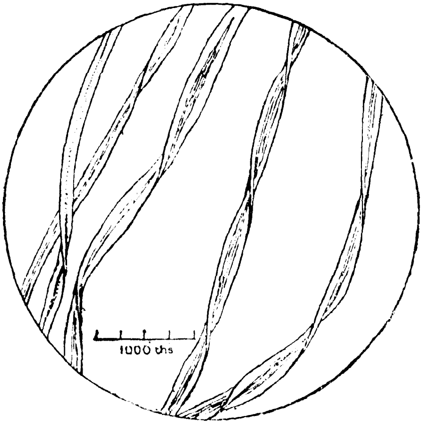

FIG. 56.—Cotton from flannelette.

Cotton filaments (Fig. 56) average about $\frac{1}{1000}$ inch thick, are flat and ribbon-like, and always recognizable by being twisted. Cotton is very durable, does not shrink when washed, absorbs moisture badly, and rapidly conducts heat away. On this account it is ill-adapted for under-garments next the skin, as, if perspiration be present, it readily induces chill. What is called "cellular cotton" is merely an ordinary cotton fabric with larger interspaces than usual in its texture. These being filled with air, which is a bad conductor of heat, cause this material to be somewhat warmer than the ordinary cotton, and a greater protection to the body against sudden changes of temperature. Similar advantages attach to "Airlin" and the various "mesh fabrics" now in the market.

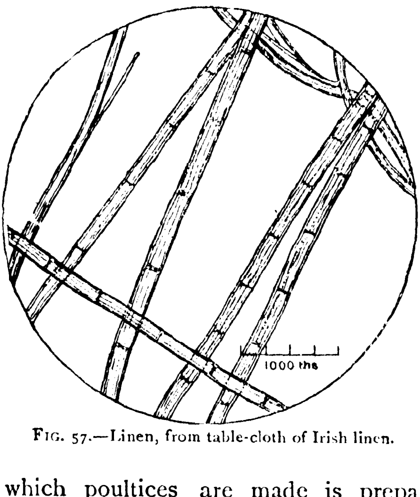

FIG. 57.—Linen, from table-cloth of Irish linen.

Flax is a fibre obtained from the stalks of a plant called the *Linum usitatissimum*, which grows to a large extent in Russia and Ireland. The seeds are the familiar linseed, from which the meal of which poultices are made is prepared, and, too, from which linseed oil and cake, the cattle food, are produced. The stalks, after being allowed to ferment or rot on the ground in the damp, are beaten and combed until something like 6 per cent. of sale-

able flax fibre is obtained from the plant. The flax fibres (Fig. 57), when seen under the microscope, are marked by transverse striæ at regular intervals; they are not flat like cotton, but more like silk, only they show a fibrous and jointed structure which is not met with in silk. Flax is much more expensive than cotton, and is used chiefly for the manufacture of linen, cambric, and lawn. Linen resembles cotton in being a good conductor of heat and a bad absorbent of moisture. It is in many respects even inferior to cotton for underclothing, but from its smoothness and lustre is unequalled as a material for collars, cuffs, and shirt-fronts. Weight for weight, flax fibre is stronger than cotton, in the ratio for single yarn of 3 to 1·8, for double yarn as 3 to 2·25, and for cloth as 3 to 2·1.

Jute is a brittle and very hygroscopic fibre obtained from the *Corchorus capsularis*, a plant growing chiefly in Bengal. Jute is not much used for clothing except as an adulteration of silk and in the making of false hair; it is chiefly employed for coarse fabrics such as mats, cheap carpets, sacking, curtains, and table-covers. It is used also as a backing for floorcloths.

Hemp is another fibre not much used in European countries for clothing. It is a coarse fibre, prepared from the stem of the *Cannabis sativa*, a plant growing in Europe, Asia, and America. It is prepared like flax and jute, and chiefly used for rope, yarn, canvas packing, and sail cloth. The Indian plant yields a narcotic drug, while hemp-seed is a popular food for birds.

Coir is a coarse, tough, harsh, yet light fibre obtained from the husk of the cocoanut. It is rarely used for clothing, but largely so for making mats, brushes, and ropes.

Indiarubber enters largely in the present day into the constitution of our clothing, chiefly because it is elastic and impermeable to water. Under the name of caoutchouc, it is the milky juice of several plants growing in Africa, Asia, and South America. Caoutchouc is a somewhat complex body, dissolving in chloroform, ether, petroleum, benzene, and carbon disulphide. Freezing impairs its elasticity, while great heat softens and melts it. Fats also destroy it. When steeped in melted sulphur at 140° C., caoutchouc becomes vulcanized. Macintosh cloth is merely a cotton or silk fabric covered, layer by layer, with a solution or paste of caoutchouc. Guttapercha is, like indiarubber, the juice of certain trees; but these grow only in the Malay peninsula. Excepting as boot soles, guttapercha is little used in clothing.

Warmth and coolness, or the power of maintaining the body heat at its normal height, being the most important property of all dress materials, it follows that our choice of clothing will depend largely upon this feature. How far a given clothing will give warmth depends upon its material, its texture, number of

layers, and its colour. Owing to fabrics conducting heat in the following order from highest to lowest, namely, linen, cotton, silk, feathers, fur, and wool, it follows that wool, fur, and feathers are the warmest materials, then silk and cotton, while linen is the coolest. The more readily a material conducts heat, of course, the cooler it feels. This heat-conducting property is mainly proportionate as to how close it is woven, and as to how little air it contains. On this account, all soft, furry fabrics, no matter whether of wool or cotton, always feel warmer than the closely woven, smooth-surfaced silks and linens. In the same way, the more layers of clothing there are, the more layers of air there are retained between them. The influence of colour is dependent upon the heat-absorbing powers of that colour. White absorbs heat the least, and is consequently the coolest; then comes yellow, red, green, blue, and black. It is obvious this effect of colour can only be of influence when outside, and that the popular idea that red flannel, when worn next the skin, or as part of an undergarment, is warmer than white is imaginary. It is a mistake to wear coloured clothing next the skin, as not unfrequently the dyes are poisonous, and, coming off, give rise to skin diseases.

✓ While affording warmth, protection from cold, wet, and injury, clothing should always be so made as not to in any way impede natural movements, nor unduly constrict any part of the body, nor be needlessly heavy, and also not afford unnatural support. The more we analyze the common forms of clothing, the more we see that their main faults are in the direction of impediment, constriction, and weight. This is particularly emphasized in the case of long and close-fitting skirts, tight sleeves, stays, garters, bands round the waist and neck, ill-fitting gloves, hats, and boots. Many of these defects and faults would be obviated if people would remember that (1) no article of clothing should be either so tight as to interfere with the circulation, or so shaped as to change the natural outline of any part of the body; (2) no garment should contain more material than is actually necessary; (3) all garments requiring suspension should be suspended directly or indirectly from the shoulders or hips.

✓ It is probably in the attire of children attending school that the greatest need of a neat hygienic dress is manifest. For girls we would suggest that each should wear a flannel chemise, blue serge knickerbockers fitted to the waist with an elastic band, and no stays of any kind. Next we would suggest a woollen jersey, and an overdress with shoulder straps fastened into the waist with a loose belt. In summer the jersey might be left off, and a cotton blouse substituted. For out-of-doors, probably a flannel hood

would be the best head-covering in winter, while in summer a head-covering is hardly needed in our climate. Such a dress as this would be not only neat and healthy, but by its smartness would raise the moral tone and help to give the self-respect which is so often lacking in children.

When possible, underclothing should be of wool in this country; in the tropics this is too heavy a material, and linen or cotton shirting is more generally suitable.

Probably no article of attire is more faulty than the boot. A properly made boot should fit the foot accurately; the great toe should be in a straight line with the inside of the foot; the shape of the sole of the boot should be taken by drawing a pencil round the outline of the foot when the weight of the body is resting on the foot, as in standing, so that the sole may be big enough to support the fully expanded foot; the material should be of soft and flexible leather; even when new, the wearer ought to be able to move all the toes with freedom in the boot; the heel should be broad and low. The stocking or sock should, whenever possible, be of a woollen material or a mixed material in which wool predominates. If no sock be worn, the boot needs to be high and close-fitting round the ankle, so as to prevent dust and stones getting into the boot. The sole of a boot should be wider than the foot, and if the boot is meant for hard wear, the excess of breadth in the sole should be considerable, so as to serve as a protection against loose stones.

Exercise.

It may be said with truth that the chief condition of health is exercise in the open air, and those who have the most of it are the healthiest. The desire for physical exertion and muscular exercise is a natural instinct; the very restlessness of the young child and of school children shows this. Our bodies possess the peculiar attribute that the more they are used, within reasonable limits, the stronger and more vigorous they become. Every one is familiar with the fact that a disused muscle wastes, becomes fatty and wanting in blood, whereas one which is judiciously used and exercised, grows, thickens, and becomes in every sense stronger. But mere exercise involves not only growth and development of the ordinary muscles of the limbs, it means also the healthy use of the heart muscle, of the muscles of respiration, of the muscular tissue of the arteries, and of the muscular elements of all parts which are capable of movement. To these must be added an increased activity of the brain and nervous system, along with a stimulation of both secreting and excreting organs.

Upon the circulating system, the effect of exercise is to rapidly increase the force and frequency of the heart's action with a consequential augmented flow of blood throughout the whole body. A healthy heart, during moderate exertion, though often beating rapidly and forcibly, does so regularly and equally; but if embarrassed, or the exercise be severe and prolonged, its pulsations may become small, quick, unequal, and irregular. A deficiency of exercise leads often to a weakening of the heart; but, on the other hand, exercise or unaccustomed exercise, suddenly and long continued, may lead to palpitation, valve disease, or other heart affections. These may be usually obviated by careful training and judicious rest. Sudden and violent exercise should be avoided by those with diseased hearts, and by those advanced in years, as in them often the circulation is unable to suddenly adapt itself to the new conditions set up.

On the lungs, the effects of exercise are to not only increase the rapidity of breathing, but also to considerably increase the amount of air inspired and the carbon dioxide expired. During exercise, the elimination of carbon is enormously increased, a fact which explains the instinctive desire of men making exertion and not restrained in the choice of food, for the various fats and sugar with a small amount of starch. When exercise is excessive or badly arranged, the circulation through the lungs may become impeded and the breathing laborious. The knowledge of this fact suggests the need to watch the action of the lungs of all men being trained for prolonged exertion.

Under exercise, the voluntary muscles grow harder and become more responsive to the will. If continuously over-exercised, their growth may change to actual wasting, due to damaged nutrition of their fibres, following either the accumulation in them of the products of their own action, or the exhaustion of their supply of oxygen; possibly both. Provided it be not pushed to such an extreme as to leave no time for cultivation of the mind, there can be no doubt but that exercise is quite consistent with, and eminently favourable to, high mental attainments and activity. The effects of exercise on digestion are such that it stimulates a desire for meat, fat, and salt, and in a less degree one for carbohydrates. The abdominal viscera act more vigorously, and the whole digestive processes are increased. The actual amount passed by the bowels during exercise seems to be slightly lessened, possibly due to less water entering the intestines.

Owing to the action of the skin being so much increased during exercise, the water and chloride of sodium of the urine diminishes; on the other hand, the uric acid, pigment, and sulphuric acid are augmented. The urea, however, is little

affected; while the actual total nitrogen excreted is, if at all increased, only so in the period of rest succeeding exertion.

The exact amount of exercise which a person takes is entirely a matter of individual decision; while what amount a healthy adult should take is not easy to fix, as a hard-and-fast rule would not fairly apply to all the varying degrees of health and strength. In this connection a word of warning is advisable. There is evidence that the modern craze for extreme and special athletic exercises is often doing more harm than good. Many of these athletes fall a prey to degenerative changes, tend to become fat and generally to lose physical stamina. Moderate athletics are to be encouraged, and in the form of Swedish system of exercises are an excellent code by which to secure the gradual development of all the body muscles. As regards ordinary exercises, such as walking, it may be laid down as a working axiom that so long as such amount or kind of exercise gives pleasure it may be undertaken, but when such is clearly distasteful or irksome it may be assumed that it is uncalled for.

Work is always expressed in units of weight lifted through a unit of height; as in terms of pounds lifted a foot, or tons lifted a foot. A fair day's work for a man of average weight and height is generally taken to be about 300 foot-tons, or the work necessary to raise 300 tons one foot high; this has been calculated to be equivalent to walking about 16 miles in a little over five hours. A hard day's work is about 450 foot-tons, equal to walking some 24 miles in eight hours; and an extremely hard day's work is from 500 to 600 foot-tons, equal to walking 26 to 32 miles in nine or eleven hours respectively. For average men, engaged in sedentary occupations, not less than 100 to 150 foot-tons of work or exercise should be performed each day, equal to walking for two hours at a moderate pace, or equal to raising the body-weight through some 500 to 600 yards in height. It is not easy to say what the work done is in mental and office work generally. These rules, it must be remembered, apply only to healthy adults, and need to be much modified in the case of young children, or those whose age or health prevents their exercising their full powers. In children, much of their power and energy goes in building up the growing body, and consequently less exercise or work can be expected of them. Thus, a child, weighing 80 lb., ought not to be called upon to do half the work done by an adult weighing 160 lb., but something less, probably in the ratio of the square of their respective weights. In a similar manner, women should not be called upon to do as hard or even harder work than the men.

No mention has been made of the internal work of the body,

such as that of the heart, respiration, digestion, etc. This has been variously estimated; but adopting a mean, we get about 260 foot-tons for all the internal mechanical work, which, added to the external labour, makes the demand, for the average person, to be about $\frac{1}{7}$ of all the force obtainable from the food consumed.

For the average man or woman walking on ordinary roads, the work done is equal to $\frac{1}{20}$ of the work done in direct ascent, or that a man walking 20 miles on the flat, at 3 miles an hour, does as much work as if he had raised his body through a mile in height. The fraction $\frac{1}{20}$ is the expression of the resistance due to traction, and varies with the velocity at which the work is performed; being $\frac{1}{38}$ for a velocity of 1 mile an hour, $\frac{1}{26}$ for 2 miles an hour, $\frac{1}{16}$ for 4 miles an hour, and $\frac{1}{14}$ for 5 miles an hour.

When a man goes up a height, he raises his whole weight through the height he ascends, and to compute the quantity of work done we must multiply the weight by the height, and an easy calculation changes this into the weight raised 1 foot.

The formula for the calculation of work done is usually written thus: $\frac{(W + W') \times D}{2240} \times C =$ foot-tons; in which W is the weight of the person, and W′ is the weight carried, both expressed in pounds; D is the distance in feet; C is the coefficient of resistance or traction; while 2240 is merely the number of pounds in a ton. The application of this formula will be more readily understood from the following examples.

Let A and B be two men. A lifts a 10-lb. hammer, $4\frac{1}{2}$ feet high, 12,000 times in eight hours. B, who weighs 10 stone, walks 14 miles on an ascent of 1 in 300 in six hours, carrying 30 lbs. on his back. It is required to know which does the harder work, and by how much.

Applying the formula to the case of A, we get $\frac{10 \times 4{\cdot}5 \times 12000}{2240}$, which, worked out, gives 241 foot-tons of labour done in eight hours.

B's case is somewhat more complicated. It involves two small calculations, one for the work done, had it all been on the flat, the other for the additional labour involved in going uphill, which is equivalent to lifting his own and load's weight a given height. The sum of these two will give his actual work done. Using the formula, we get B's work on the flat to stand thus, after reducing the stones to pounds and the miles to feet—

$$\frac{(140 + 30) \times 14 \times 5280}{2240} \times \frac{1}{20} = 280\tfrac{1}{2} \text{ foot-tons}$$

As the rise is 1 in 300, we get for the second part of the state-

ment, the lifting of the man's body-weight and load, a height of $\frac{14 \times 5280}{300} = 246 \cdot 4$ feet, or $\frac{(140 + 30) \times 246 \cdot 4}{2240} = 18 \cdot 7$ foot-tons. Then adding these two results together or $280 \cdot 5 + 18 \cdot 7 = 299 \cdot 2$ foot-tons as the work B does in six hours.

In attempting to compare B's work with A's, we must allow for the fact that B does his in $\frac{3}{4}$ the time that A took, or six hours as compared with eight hours. Therefore, to obtain a fair comparison, we must multiply B's work of 299 foot-tons by 4, and divide by 3 or $299 \times \frac{4}{3} = 398$ foot-tons of labour performed by B, while A only did 241 foot-tons, or 157 foot-tons of work done by B more than by A, if both had been working at the same speed.

CHAPTER VII.

CHILD WELFARE AND SCHOOL HYGIENE.

THE high rate of infantile mortality which prevailed in this country for so many years directed attention to the lamentable loss of life which was going on, and due largely to ignorance on the part of mothers and their adherence to faulty methods in the rearing of infants. The outcome of attention directed to this matter resulted in the development of a powerful and efficient movement known as "child welfare." The earliest step in the movement was to provide in districts trained and experienced women visitors to give advice and encouragement to mothers of the poorer classes as to the proper methods of rearing their children. The movement was much helped by the Notification of Births Act, 1907, whereby the existence and location of young infants was made readily available to sanitary authorities. Material support being rendered by the central government, the movement was soon adopted by the sanitary authorities, who then formed child welfare centres and clinics. In the early days of the movement, the work was confined mainly to infants, but its success in controlling mortality was so marked that the present aim of all complete schemes of child welfare is to control and supervise the up-rearing of children not only during infancy but also up to the age of five years. In recent years, the movement has developed further and embraces the watching over of the

health of the expectant mother, of bringing to full term and safe delivery of children whose lives were lost to the nation formerly as the result of abortions and miscarriages. These efforts are maintained by the provision of skilled attendants or midwives.

In this manner is the solution of the infant mortality problem being reached. The machinery brought into play is extensive, and aims at more than efficient domestic or municipal sanitation. It means intelligent and painstaking motherhood fostered or controlled by both paid official and voluntary women health visitors, coupled with organized schools for mothers, consultation centres for mothers, infant milk depôts, the provision of cheap meals to expectant and nursing mothers, clinics for mothers and infants, and some hospital accommodation for expectant mothers during pregnancy, and also for infants. To these provisions must be added the assistance of one or more doctors to co-operate with the health visitors. As a general rule, the smaller sanitary areas can be served more economically and efficiently by a county scheme than by separate schemes for each district, provided that proper co-operation with the sanitary authority is secured. A County Council can combine in one individual officer the duties of health visitor, inspector of midwives, tuberculosis visitor, and occasionally those of school nurse and mental deficiency visitor, and thus save expense and time whilst securing also uniformity of work and direction. Local authorities should, as a rule, aim at securing a staff equal to one whole-time health visitor for each 500 births. It is, moreover, important that the visiting of children be extended to school age, and that ante-natal visiting should be undertaken. The work of health visitors may include properly the visiting of cases of measles, whooping cough, and diarrhœa in young children.

A woman is qualified to be a health visitor if she is (1) a qualified medical practitioner; (2) a nurse who has undergone for three years at least a course of instruction in the wards of any hospital or infirmary being a training school for nurses, and having a resident medical officer; (3) is certified under the Midwives Act, 1902; (4) has for a period of not less than six months undergone in a hospital or infirmary receiving children as well as adults, and having a resident medical officer, a course of instruction including subjects relating to personal hygiene, and holds a certificate of the Royal Sanitary Institute for health visitors and school nurses, or the certificate or diploma of the National Health Society, or of any other body approved by the Ministry of Health; (5) has in the service of any sanitary authority or public body in England and Wales, discharged duties similar to those of a health visitor, and produces evidence of

competency; (6) when the circumstances so require, a woman may be appointed who holds none of the above qualifications (1 to 5), but has a competent knowledge and experience of the theory and practice of nurture, of the care and management of young children, of attendance on women in and immediately after child-birth, and of nursing attendance in cases of sickness or other mental and bodily infirmity. In practice, the health visitors work under the instruction of the medical officer of health of the area.

When it is remembered that about 3 per cent. of the total births notified are still-births, the need of ante-natal clinics is manifest. Further, since for every still-birth after the seventh month of pregnancy there are at least four abortions between conception and the seventh month, it follows that for every 100 children born alive some 15 have died *in utero*. This means that the fatality among the unborn is higher than the fatality of infants in the first year of life. If all women were under skilled observation during pregnancy, it is probable that about half the ante-natal deaths that now occur could be prevented and the number of infants born prematurely and of feeble constitution could be much reduced. At least one-fourth of the children who die in the first year of life die during the first week; most of these deaths and of those who die within the first three months are due to ante-natal conditions of the mother and might have been remedied by ante-natal attention. In any scheme of ante-natal care there must be an ante-natal clinic, held weekly or fortnightly at a recognized centre by a skilled gynecologist coupled with home visiting of pregnant women by a trained health visitor. The inquiries made by the health visitor should be entered on a prematernity card and produced at the clinic for the information of the doctor. The woman's visit to the clinic must be recorded on the card, and the medical advice given or treatment recommended. Subsequent visits to the woman at home by the health visitor will be directed to see that the instructions are being carried out, and that all proper steps are taken to prepare for the approaching confinement. This action is materially helped by the maternity benefit available under the National Insurance Act, 1911.

While much can be done by this ante-natal work, and also by home visitation on the part of the health visitor whereby observation can be made as to conditions, and the giving of sound instruction to mothers as to the right way of nurturing their young children, it is obvious that furthur advantages may be derived from the provision of Infant Care or Child Welfare Centres to which parents may bring their infants on certain afternoons. Not only can the infant be weighed, but the recording of the

results be better and more expeditiously performed, but the arrangement results in a saving of time for the health visitor. Further, the establishment of a Centre allows of the temporary assistance of a medical man to advise the mothers and help the health visitor. In most large towns and populous centres, schools for mothers or child-welfare centres have been established. The Centre should comprise at least three rooms; one as a weighing-room for babies, one a waiting-room, and one for the doctor. The centre must be convenient of access for the poorer class of mothers, and the consultations should be held in the afternoon one day a week throughout the year. Records must be kept of the attendances, with the weight of the babies, and the instructions or advice given in each case. Treatment of simple ailments can be given on the spot, or the mother referred to a hospital, dispensary, or medical practitioner. Advantage may be taken of these visits to the Centre to give informal talks to the mothers on nursing, cooking, and how to make clothes for infants. The health visitors should visit newly born infants ten days after birth, at which time the midwife usually ceases to visit. Mothers should bring their infants to the Centre regularly, say once a fortnight. The child or children should be visited by the health visitors until they are one year old, and in cases where progress is not satisfactory, the mother inclined to be negligent, or fails to bring her infant regularly to the Centre, the visits must be frequent. The visits need to be kept up, perhaps at longer intervals, after the first year of life and the mother encouraged to bring the child to the Centre for inspection if its health is unsatisfactory. As a rule, visits may cease at the age of five, or earlier if the child has been entered on a school register, and the records so accumulated as to its condition at various ages should then be passed on for the use of the school medical inspector. Every endeavour should be made to encourage breast-feeding; in many towns municipal milk depôts have been established in which pure pasteurized milk or dried milk is provided for those infants who are not breast-fed. On these lines, child welfare schemes are doing much good work and are full of promise to prevent many of the disabling illnesses of early childhood, and the child given a good prospect of entering upon its school life in good health. This newer policy is no question of helping the survival of the unfit; it must be regarded rather as aiming at the survival of children under conditions of healthy normal development and who, in due time, should be best fitted to become capable, healthy future citizens.

Attention should be directed to the Children Act, 1908. Its first part relates to the control of baby farmers, who must notify

the Board of Guardians of any child received by them, and provides for their periodical inspection by an officer of the Board. Under this Act it is a punishable offence to overlay, whilst under the influence of drink, an infant under three years of age. Further, if any person over the age of sixteen, who has the charge of any child and wilfully assaults, ill-treats, neglects, abandons, or exposes the child in such a manner as to cause unnecessary suffering or injury to its health, he or she is liable to a fine of £100 or imprisonment for two years with hard labour. It is also an offence to leave a child under seven years of age in a room where there is an open fire, unless there be an adequate fireguard to prevent the child being burnt. The penalty is £10 if the child be killed or suffers serious injury. The Act also enables Local Education Authorities to cleanse verminous school children, and provides a penalty to be inflicted on the parents if the child, after being cleansed, is allowed to become verminous again.

The general principles governing the arrangements of school buildings have been considered elsewhere in a previous chapter, there remains, however, some points connected with the school child which have a sanitary importance. It is a recognized principle in school hygiene that there is nothing more disabling from the standpoint both of the teacher and the taught than foul air, and the objects kept in view in all structural arrangements of the school building have been shown to be directed to improve and maintain the atmospheric conditions in the classroom, as conducive to improve the quality and amount of work performed. In this manner the effects and value of environment of school life are twofold, that is, physical and educational. The latter may be purely educational, in that the scholar is affected by sanitary precept and practice, or it may itself have physical results by favouring or otherwise the mental response and consequent general educational results.

Under the Elementary Education Acts, 1876 and 1899, children from 5 to 14 years of age must attend school; and under the Elementary Education (Defective and Epileptic Children) and the (Blind and Deaf Children) Acts, 1899 and 1893, parents must cause abnormal children to receive education up to 16 years of age. In all classes of children attending schools, the ever-present danger is brain-fatigue and over-pressure. This danger is most acute in schools attended by the children of the poor, and the scholars especially liable to suffer from over-pressure are the delicate nervous children, the constitutionally weak, the anæmic and badly fed, also the rapidly growing, excitable, and mentally precocious children. To these must be added, those

exposed to bad air or bad conditions of study, bad teaching and unhealthy home conditions, those getting too little sleep and recreation, those suffering from defects of sight or hearing, and those at the period of puberty. The prevention of brain fatigue turns largely on there being a school time table which economizes brain energy and directs it on right lines. This means short lessons not exceeding half an hour, a proper sequence and variation of subjects, proper regard to stage of development of the scholar, sufficient intervals for rest, recreation, exercise, and food, fresh air, quiet classrooms, coupled with a strict limitation of the subjects selected for, and the duration of, the home lessons. Home work should never take more than an hour to prepare, and ought never to be given to children below ten years of age. Up to five years of age, a child should be educated through the senses and their activities, then the memory should be developed and good habits cultivated. After ten years of age the child's reasoning powers and imagination develop. Psychologically, the young child is very imitative, craves for approval, is naturally curious and full of activities; these latter need to be controlled and directed to useful educational ends. On admission to school, every child should be examined as to both vision and hearing. Early attention to these two senses will either lead to a cure or will prevent matters going from bad to worse. For children over eight years of age, the school curriculum should include a course of organized games to draw out and develop physical, mental, and moral qualities. In addition, certain drill exercises are needed which in older children, say over 14, may well be replaced by gymnastics. Better results are obtained from daily short physical exercises than from longer exercises of greater intervals.

Little attention appears to be paid to the clothing of school-children. It should be both light and loose, so as not to interfere with any natural function or movement; it must be distributed suitably, so as to regulate the body temperature and guard against chills. The most common and yet easily corrected errors in the clothing of school-children relate to articles which by their pressure and constriction either interfere with the circulation of the blood or lead to deformities; for example, tight neck-bands or collars, garters, stays, belts, braces, and heavy ill-fitting boots.

In respect of food, it may be accepted that in terms of water-free constituents the daily diet of a child of seven years should not contain less than 2 ozs. of protein, 2·3 ozs. of fats, and 8 ozs. of carbohydrates; at ten years of age, the daily need is protein 2·5 ozs., fats 3 ozs., and carbohydrates 10·7 ozs.; at fourteen years of age, the daily need is protein 3 ozs., fats 3·5 ozs., and carbo-

hydrates 12·7 ozs. The Education (Provision of Meals) Act, 1906, enables Education Authorities to provide meals for school-children, and to recover the cost from the parent, where possible. Where this is done, supplementary advantage is gained if elder girls can be made to assist in the cooking. In general terms, the diet of school-children should not contain too much meat. Raw apples and nuts and all kinds of fruit are desirable. If sweets or chocolates are given they should be given in reasonable quantity at the end of a meal, and after the appetite has been blunted or more or less satisfied.

The medical inspection of school-children is imposed upon local Education Authorities by the Education (Administrative Provisions) Act, 1907, at the time of the child's first admission to a public elementary school and at such other times as the Board of Education may direct. The second inspection is usually at the age of 8, and a final inspection made usually at the age of 12 to 13, or one year before the child leaves school. This work of medical inspection is of great sanitary importance, and wherever a sanitary authority employs a female staff, a member of that staff should be present to render assistance to the inspecting medical officer. The female sanitary inspector must not be confused with the school nurse, whose duties are to attend to minor ailments of children irrespective of the medical inspection. The mothers are always invited to be present at inspections, so that they may receive instructions from the doctor. The medical officer of health usually supervises the work of inspection which is carried out by assistants. It is regrettable to have to say that of 1,056,315 children inspected not long ago in different parts of England and Wales, no less than 2727 were found to be suffering from phthisis and 3162 others from other forms of tuberculosis. One-sixth of the children of school age are so dull and backward as to be unable to derive reasonable benefit from schooling, half the school-children are in need of dental treatment, and one-twelfth of the children are so defective in eyesight as to be unable to take full advantage of their lessons. Many children of delicate constitution, threatened with or possibly suffering from the early stages of phthisis or other forms of tuberculosis, may with great advantage be taught in schools specially adapted to their needs. Several schools of this kind, in which fresh air, sunlight, good food, and special attention are features, have been established in many parts of the country.

Elementary public schools are a fruitful source of spreading infectious diseases. The only control towards a mitigation of the evil are the compulsory information supplied under the Infectious Disease Notification Acts and that furnished by

teachers and others as to whooping-cough, chicken-pox, etc, in the districts where these diseases are not compulsorily notifiable. On receipt of information of a case of infectious disease in a child attending school, the medical officer of health informs the school authorities, so that all children from the same house may be excluded from school until the premises are declared free from infection. If the case be promptly removed to an isolation hospital, the clothes and bedding can be disinfected at once, and the other children then allowed to return to school on the expiration of the number of days corresponding to the maximum incubation period of the disease in question. If the child attacked is treated at home, then the other children in the house must be excluded from school until the patient has recovered and all bedding, clothes, and other sources of possible infection disinfected. Small-pox, typhus, scarlet fever, diphtheria, measles, whooping-cough, and cerebro-spinal meningitis are the diseases for which these precautions are most necessary.

By issuing a certificate, endorsed by the sanitary authority or any two members of it, the medical officer of health has power to close a school, or he may obtain such closure by getting the formal approval thereto of the school medical officer. The closing of schools may seriously interfere with the educational work of a locality, and is a step which should only be taken after most careful consideration. The character of the evidence that the school is the centre of infection must be well weighed, and the nature of the action to be taken will vary under different conditions. It is difficult to lay down definite rules as to when or for how long a school or schools should be closed. The nature of the disease, its character, the number of pupils affected, will all be factors in deciding the point, as well as the nature of proof that the sources of infection are really at the school. Much depends upon the amount and promptness of the information which the medical officer of health is able to gain in regard to the circumstances of the school children and their homes, and the promptness with which action can be taken. Closure of schools is less likely to be efficacious in checking diseases such as measles in a densely populated area than in a sparsely populated one, because the opportunities for intercommunication are so much greater in the one than in the other. What applies to public elementary schools also applies to Sunday schools and private schools. When it does become expedient to close schools, it is desirable that the time specified be a minimum. In certain circumstances the closure of a class is preferable to the closure of a whole school. In the case of measles, for instance, it often happens that practically all the children in the upper classes of

somidæ occur in fish, amphibia, reptiles, birds, and mammals. Most of these are incompletely known, and only recently a few forms have acquired great importance from the fact that they cause more or less serious disease in man and animals. Thus, *T. evansi* is the parasitic trypanosome causing a disease called surra in horses in India ; other varieties cause similar disease among horses in Algeria, Central and South America. *T. brucei* is the highly pathogenic trypanosome of tsetse-fly disease or ngana, an infection of cattle in South Africa conveyed by means of a species of glossina or tsetse-fly. *T. ugandiense* is the notorious parasite found in the cerebro-spinal fluid of cases of sleeping sickness. It is conveyed from person to person by means of a biting fly known as glossina palpalis. These are the more important trypanosomes, but there are several others known to be associated with certain obscure diseases of animals.

The life history of the trypanosomes is imperfectly known, but, with one exception, all the species which have been investigated have a second host, which is an invertebrate of some kind. The exception is the *T. equiperdum* of a disease in horses known as dourine, in which the parasite is said to pass direct from a sick animal to a healthy one. The intermediate host in the other cases is a blood-sucking invertebrate, and in this host alone does the sexual cycle take place.

Spirochætes.—This genus appears to be allied closely to the trypanosomes, and some important parasitic forms have been referred to it. These parasitic micro-organisms have the appearance of minute slender threads, wavy or spirally twisted in form (Fig. 63). The true type of this genius is *S. plicatilis*, which has an undulating membrane, no trace of flagella, a blunt round end, and a unclear apparatus of a thread-like nature. Among the more important pathogenic members of this genus are the *S. obermeiri* of relapsing fever conveyed from man to man by the bug; *S. duttoni* or the parasite of human tick-fever conveyed by the tick ornithodoros moubata; the *S. pertenuis* of yaws, and the *Treponema pallidum* or infecting micro-organism of syphilis.

Leishmania.—Under this heading we refer to certain human parasites which are still the subject of some controversy. These are the so-called Leishman-Donovan bodies found in the spleen and other organs in Kala-azar and oriental sore. These parasites are typically intracellular, being found as ovoid or pyriform bodies in leucocytes and cells of endothelial nature. When cultivated in suitable media and at moderate temperature, the Leishman-Donovan bodies undergo changes which result in their becoming flagellate organisms. Nothing is known of the natural development of these parasites outside the human body, but it is suspected

that some form of arthropod like a bug or tick is the intermediary host. It is not unlikely that there exists some minute spirillar stage which is ultra microscopic.

Coccidium Hominis.—This is probably the same species as attacks the intestinal epithelium of rabbits. The infection of man by this parasite is associated with serious symptoms, such as fever,

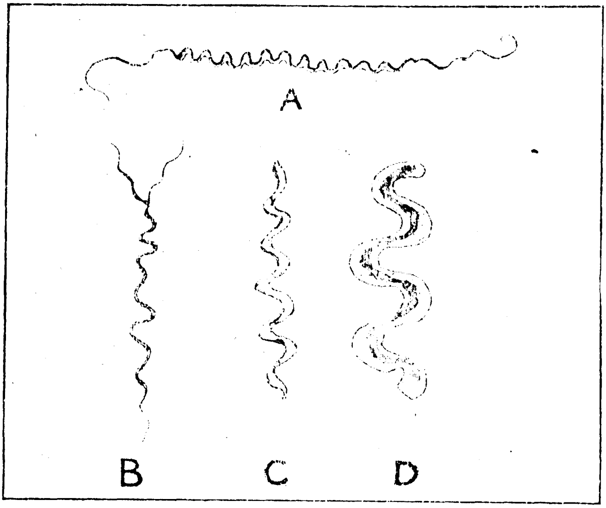

FIG. 63.—Varieties of Spirochætes.

A and B, *Treponema pallidum*. C, *Spirochæta refringens*. D, *Spirochæta plicatilis*.

diarrhœa, and enlarged liver. These parasites are minute spherical bodies, rarely more than a millimetre in size, attacking the epithelium of the bowel or the cells of the liver. Fortunately, infection of man by these coccidia is rare, but in rabbits it is fairly common.

Plasmodium Malariæ.—Three varieties of this species parasitic to man are recognized: *P. malariæ* or the parasite of quartan ague, *P. vivax* or the benign tertian parasite, and *P. immaculatum* or the parasite of malignant tertian malaria. Other species of the genus affect monkeys, birds, bats, and even reptiles. The life cycle of the malarial parasite has been explained elsewhere, and also its intimate association with a certain variety of mosquito, which is its intermediate host.

Piroplasma.—In this family are included a number of organisms which are parasitic to cattle and dogs, but only one

which is apparently parasitic to man. This is the *P. hominis*, the cause of the tick fever of the Rocky Mountains. The parasites are very minute pear-shaped forms occurring singly or in pairs inside blood corpuscles. Very little is known regarding the life cycle of the piroplasmata, but the intermediary host in all cases appears to be a tick.

Scabies, or itch, is caused by the burrowing into the skin of an insect called the *Acarus scabiei* (Fig. 64). This burrowing excites much itching and some rash. It is the female itch insect which thus burrows and causes the characteristic symptoms of this disease; for, burrowing beneath the cuticle, she lays her eggs at the end of the burrow, where they hatch, and the young insects then commence to burrow afresh in other directions. A very common place for itch to begin at is in the spaces between the fingers, and from out of the burrows, here or elsewhere, the acarus can be dug out by a needle, if carefully looked for. The irritation which these insects set up is most intense, and often gives rise to eruptions of pimples, blisters or pustules, which readily obscure the true nature of the affection. Owing to the ready means by which the itch insect can pass from one person to another, itch is eminently contagious, and the greatest care needs to be taken in separating those affected with the parasite from those who are free, and too, the most careful disinfection of all clothing which has been worn by the sufferer. For the actual cure of the itch, sulphur ointment is the best remedy, but needs to be supplemented by scrubbing the skin with soft soap and hot water. This scrubbing removes the loose scurf or scales of the skin, and helps the action of the sulphur by exposing the insect in its furrows.

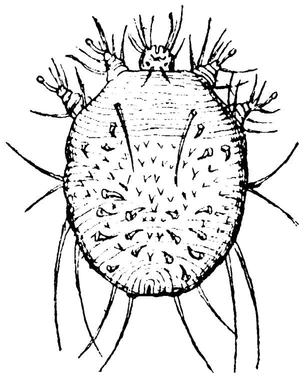

FIG. 64.—*Acarus scabiei.*

The **louse**, or *pediculus*, may infest either the hair of the head or the body, in both of which parts it gives rise to characteristic irritation. Lice in the hair are quickly killed by saturating the hair with an ointment of corrosive sublimate; but a difficulty often exists in destroying their eggs or nits, which adhere to the hairs by means of a gummy matter. This can usually be dissolved by means of methylated spirits, and the nits detached by careful combing. The constant use of warm baths, soap, and

scrupulous cleanliness are essential aids to keeping away the pediculi. The clothes of those affected with the body variety require exposure for some hours to a dry heat of not less than 220° F., or else to be treated by one or other of the disinfection methods as detailed in the last chapter.

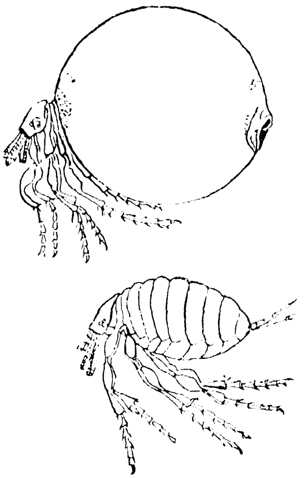

FIG. 65.—*Pulex penetrans*. Female and male.

Fleas and bugs are, in a sense, parasitic, but possibly less so than a special variety of flea met with in some parts of the tropics, called the chigoe, or *Pulex penetrans* (Fig. 65). These insects give rise to considerable pain and irritation, accompanied by swelling of the parts attacked. It is only the female insect which gives rise to these symptoms. While the male retains the ordinary form and habits of a flea, the female bores her way into the skin of the foot in man, dogs, and other animals, and becomes, by the enormous development of the ovary, a simple motionless bladder embedded in the flesh, around which, in course of time, when the eggs have to be extruded, a certain amount of inflammation arises.

Fleas, Bugs, Ticks, and other insects are not only of interest because they bite, suck blood, and are parasitic on man and animals, but on account of the fact that they serve as hosts for the conveyance of germs and other parasites from animals to man and from man to man. Thus *Pulex cheopis* or the common flea of rats in India is concerned in the transmission of plague bacilli, not only from rats to rats, but from these and other infected animals to man.

As regards bugs and ticks, especially the latter, considerable evidence has accumulated showing that these arthropods are intimately associated with the spread of disease. Thus, *Rhipicephalus annulatus* and *R. Appendiculatus* are two ticks common in Texas, Queensland, and South Africa, which transmit the germs of red-water fever among cattle; in a similar manner another tick, *Dermacentor reticulatus*, is associated with the spread of Rocky Mountain fever in the Western States of North America. Other ticks convey corresponding diseases among sheep and dogs, while the *Ornithodoros moubata* is a tick found in the Congo Free State

and Sudan which conveys the infection of relapsing fever from man to man.

The life history of a tick is briefly as follows: The female deposits her eggs in masses on the ground, and then gradually shrivels up and dies. The favourite place for ovi-deposition is on grass or coarse herbage. The egg-stage varies from eight to twenty-two weeks, and then gives rise to the larval form. These larvæ are six-legged and soon crawl up grasses and plants, waiting to become attached to some passing host. The larval ticks feed upon the blood of the host and when repleted fall to the ground. Here they moult and change to the nymph or pupal stage, which has four pairs of legs. The pupa acts just as the larva, crawling up grass and there waiting to regain a host. Having done so and gorged blood, the nymph falls to the ground and remains there a variable time, sometimes as long as three months. It then moults and becomes an adult male or female tick, which, regaining a host, feeds on its blood and then repeats the cycle. Ticks may live a long time away from the host, provided they have moisture. There seems to be no pressing necessity for a tick to secure a host, for even if starved and growth be arrested, the longevity is marked; on the other hand, feeding on a host appears to be essential for growth and exuviation, and under these favourable conditions life is often brief. Although in the majority of species of ticks, each individual must find a host three times in the course of its existence, namely, in its larval, nymphal, and adult stages, there are notable exceptions to this rule. Thus, *Rhipicephalus annulatus* effects both moults upon one host; *R. bursa* makes its first moult on the host and its second on the ground, thus needing a host twice; *R. Appendiculatus* effects both moults on the ground, thus needing three hosts. Alternative stages are exemplified by *Hyalomma hebræum*, which is apparently parasitic only in adult condition, while, in the case of *Ornithodorus moubata*, the larval stage is passed within the egg-shell, so that the nymph in reality emerges from the egg.

Among the other insects which have a parasitic interest are the mosquitoes and gad-flies. These are all blood-suckers on man or beast, and play an important part in the conveyance of infection. The various genera of *anopheline* mosquitoes are the means of transmitting malarial germs from one man to another, while certain *culicine* mosquitoes are connected with the transmission of certain micro-filaria and also of the germ of yellow fever.

Of the larger blood-sucking flies, the most important is the *Glossina palpalis*, a species of tsetse fly, which transmits the trypanosome of sleeping sickness in Uganda and other parts of Central Africa. Another tsetse fly or *Gl. morsitans* transmits

from oxen and horses the infecting trypanosome of ngana cattle disease in South Africa. An allied species of fly, the *Stomoxys calcitrans*, appears to be associated with the dissemination of the trypanosome of surra among horses in India. In addition to the foregoing, various other large flies are parasitic in their larval stage on man. The more notorious of these are *Sarcophaga carnaria*, *Ochromyia anthropophaga*, and *Bengalia depressa*, whose larvæ penetrate the skin, produce severe ulcers and other repulsive ravages on man in tropical countries.

Guinea-worm, or the *Filaria medinensis*, is a formidable parasite, which, in some parts of Africa and India, gives rise to boil-like swellings and sores upon the ankles and legs. There has been much controversy as to how this worm gains entrance into man's system, some maintaining that the entrance is gained through the skin, either by a minute worm passing into a sweat-duct, or by a minute embryo coming in contact with a broken surface of skin; while others maintain that it always obtains entrance into the body by means of the drinking-water, and then works its way to the superficial parts at which it is generally found. At present this point is not definitely settled, but the opinion is gaining ground that the parasite enters the human body by means of drinking-water. The worm is about $\frac{1}{10}$ inch in diameter, and usually from 1 to 3 feet long. Like many other animal parasites, its presence in the tissues of man is but a portion of its life-history, and to complete its cycle of existence it requires to pass into the tissues of some other living organism. So far as is known at present, the history of this worm amounts to this. The worm having gained access to man's body in an embryonic state, requires some nine months for its development, and it is only when the stage of maturity is reached and the eggs are about to be hatched that symptoms, in the form of an abscess or boil-like swelling, appear which in any way indicate its presence in the human tissues. The embryo which is emitted from man is aquatic in habit, and to further develop needs to pass into water. In this medium it meets with a fresh-water crustacean (*cyclops*), whose skin it quickly perforates, and in whose body it undergoes a certain degree of larval growth, and afterwards, with its host, the crustacean, reaches the inside of man, most probably by drinking-water. Its subsequent history in man is not known, but the inference is, that it burrows its way to the body surface in time to seek and secure an exit for its embryos into fresh water, in which medium they pass again through the changes already mentioned. This passing through one or more hosts, or individual living organisms, is characteristic of several other animal parasites of man, more particularly of the

following, which mainly infest various parts of man's intestines or other viscera.

Filaria Sanguinis Hominis.—This is a minute hair-like worm, often reaching a length of 3 or 4 inches, found in the blood of men who have lived in certain tropical countries. It is considered to be the young form of another *filaria*-like worm, which, in the sexual state, is found in the lymphatics of the subcutaneous connective tissue of persons suffering from two peculiar diseases called chyluria and elephantiasis. The former is marked by periodic attacks, in which the urine becomes milky and, upon standing, coagulates. This condition has been traced to an admixture of urine with lymph, and in which immature filariæ are visible under the microscope. Elephantiasis is attended by an enormous enlargement of the limbs and generative organs. The life-history of the *Filaria sanguinis hominis* is very curious. The parent worm, or that usually associated with chyluria and elephantiasis, and known as the *Filaria Bancrofti*, lies in a lymphatic, and here emits her young into the lymph stream, along which they pass through the thoracic duct into the blood. In the blood, these embryos or young are known as the *Filaria sanguinis hominis nocturna*, in consequence of their exhibiting there an extraordinary periodicity, abounding in the night time, but disappearing during the day, when they probably lie at rest in some abdominal or thoracic viscera. This periodicity is for some unknown reason an adaptation to the habits of the mosquito, which is the intermediate host of this parasite. The mosquito, as every one knows, is most active at night, and when it bites the human host, these filariæ curl round its proboscis and are then quickly transferred to its stomach. The greater number of the filariæ so swallowed by the mosquito are digested or destroyed, but a certain few undergo development inside its body, and, when the mosquito retires to some water to lay eggs, or to eventually die, these filariæ which have developed inside its body pass out by boring into the water, whence they get swallowed by man. Once inside the human stomach, the filariæ bore their way into the lymphatics, finally reaching their permanent abode in some distant lymph-vessel, where, as the *Filariæ Bancrofti*, they give rise to chyluria and elephantiasis, and breed, their progeny passing into the blood as before explained, till, released by the mosquito, they in their turn can complete their cycle of development. Such being the history of this remarkable parasite, it follows that, to prevent people getting affected with it, all water in filaria districts should be boiled and filtered.

Anchylostoma.—This is a short worm, about $\frac{1}{2}$ inch long, which attaches itself, often in large numbers, to the villi of the

small intestine. It is common in Egypt and some parts of Italy, where, on account of the large amount of blood which it abstracts, it produces a serious and fatal form of anæmia known as anchylostomiasis. The mature eggs of the worm, on being discharged from the patient's intestines, undergo their primary stage of development in wet soil, being much favoured by a high temperature. In the warm damp earth the parasite leads a free existence, and assumes a slightly different shape to that which it presents when in the human bowel; instead of being rather short and stumpy, it is long and thin. The anchylostoma has only one host, namely man. Recent researches show that the most common mode of entry is through the hair follicles of the skin, though it is possible to convey the larvæ to the mouth and food by means of the hands, especially in the case of workers with soil or mud, such as agriculturists, canal workers, and miners. Entering the skin the larvæ bore their way to the heart and lungs. Thence they bore their way to the œsophagus attaining their ultimate destination in the intestine.

It is evident from the life-history of the anchylostoma, that any attempts at prophylaxis are summed up in efforts to prevent the ripe larvæ entering the body. This can be secured either by personal hygienic precautions against ingestion of larvæ by the mouth and skin infection, or by precluding development of larvæ once the eggs leave man's body. Air-borne infection is most improbable; in mines and agricultural pursuits the most serious risk of infection is by dirty hands and working bare-footed in mud or water. If contamination of the ground by human fæces can be prevented there is no possibility of anchylostomiasis spreading, as ripe larvæ then cannot reach those who would otherwise be exposed to infection. As the disease is absent as an endemic affection in any town or community with a moderately good system of excreta removal, the elaboration of some such system is clearly the simplest preventive measure.

Trichina Spiralis.—This is a small worm, varying from $\frac{1}{18}$ to $\frac{1}{8}$ inch in length, which attacks not only man, but also pigs and other animals, producing the disease known as trichinosis. In this disease the muscles present a number of ovoid cysts about $\frac{1}{70}$ inch in length, just visible to the naked eye, within which is coiled an immature trichina, not much more than $\frac{1}{40}$ inch long (Fig. 66). If by chance the tissue or muscle containing the capsule be eaten, the capsule is dissolved, and the young worm set free, these rapidly develop, and breed so rapidly that within a week the embryos of the trichina, by burrowing through the walls of the intestine, are able to find their way into all parts of the consumer's body, especially the muscles, in which they soon

get encapsuled, to go through the same history again. When trichinosis occurs in man, it is generally due to the eating of the imperfectly cooked flesh of pigs suffering from the disease. It is somewhat common in Germany, where sausages, hams, and pork are more eaten than in this country. The symptoms of trichinosis are sickness, prostration, fever, and muscular pains. The mortality is often slight, but occasionally very high. Recent observations show that rats inhabiting abattoirs suffer largely from trichinosis, contracted by their feeding upon the trimmings and condemned portions of diseased pigs. In view of the well-known tendency of rats to feed upon their own dead, and to frequent styes where pigs are kept, the necessity is great to keep these vermin down and to properly dispose of or destroy all offal and trimmings so that no vermin may reach them.

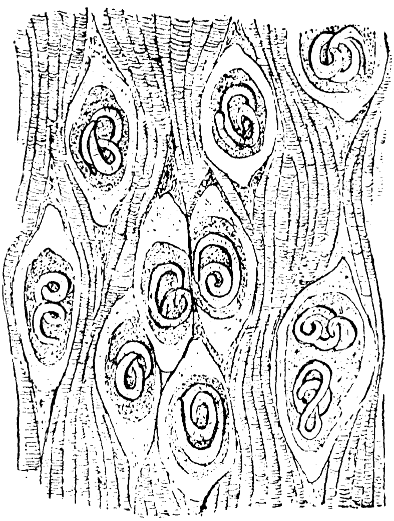

FIG. 66.—Muscle containing trichinæ.

Ascarides.—Under this name is included a large family of intestinal parasites. Of those affecting man there are three chief varieties: namely, the lumbricus or round worm, the thread worm, and a tropical kind called *Tricocephalus dispar*. The common round worm, or *Ascaris lumbricoides*, is very like an ordinary earth worm; it is pinkish in colour, tapering at each end, and some 6 inches long in the case of the males, and 12 inches in the case of the females. In man, it usually infests the small intestine, where it gives off large numbers of eggs, which are oval, nodulated, and about $\frac{1}{450}$ inch in diameter. How and where the eggs develop is not known, but it is supposed to be in some intermediate host, possibly an aquatic host; it is chiefly through water that they appear to reach man. The thread worm, or *Oxyuris vermicularis*, is a well-known human parasite, occurring in large numbers in the rectum. The female is about $\frac{1}{2}$ inch long, and the male $\frac{1}{4}$ inch. This worm gives off enormous numbers of oval, unsymmetrical eggs, each being $\frac{1}{500}$ inch long, and about half as broad. Improperly cooked or raw vegetables and water

are the vehicles by which they directly reach man from outside. The *Tricocephalus dispar* is possibly the most common of all intestinal parasites affecting man in the tropics. Its eggs are voided into the bowel, and when discharged from the bowel the embryo is not differentiated; its development remains in abeyance until the egg is carried into water or some damp medium. This happening, development proceeds, and on the egg being swallowed by man in his drinking-water, the embryo is liberated in the alimentary canal, and attaches itself to the mucous membrane of the cæcum.

Bilharzia Hæmatobia.—This is another worm parasite, about $\frac{1}{4}$ inch long, which infests the veins of the large intestine, bladder, and kidney, and gives rise to inflammation of these parts with the passing of blood in the urine. It is prevalent in Egypt, South Africa, and elsewhere. The urine usually contains the ova, or eggs, of the parasite, which are not more than $\frac{1}{180}$ inch in size, having, commonly, a sharp spine at one end. The bilharzia probably gains access to the human body through drinking-water, as we can follow the ova in their escape by way of the urine from the body of the primary host. In water, these ova hatch into minute ciliated embryos, which have been traced into the bodies of certain fresh-water arthropodes, which appear to play the part of intermediate hosts for them, in the same way as certain fresh-water crustaceans do for the embryos of the guinea-worm. If the water be drunk containing these arthropodes, the transference of these embryos of the bilharzia to man is as simple as it is certain.

Tapeworms.—These are a very common form of parasite in man, both at home and abroad; their life-histories are also peculiar, as they show that these parasites pass through two distinct phases in two different hosts. One phase of their existence is that in which the head, or *scolex* as it is called, of the parasite, together with a kind of bladder-like expansion, is embedded in muscle or other solid tissue. The bladder-like expansion or cyst is called a *cysticercus.* If the flesh containing these cysticerci is eaten by any other animal, the scolex or head reaches the intestine of its new host or the consumer, attaches itself to the wall of the intestine, and loses its cyst. Gradually, now from this head grow a series of segments, each of which is square or oblong, and each of which, too, is provided with double sexual organs. The segments are often called *proglottides*, and the chain or complete series of them may reach a length of many feet, the whole constituting the tapeworm. Each of the segments produces eggs or ova; these escape into the host's bowels, and are voided by him in his excreta. Some of the ova become attached

to grass, or other vegetables, and with them are consumed by an herbivorous animal in whose interior the embryo develops from the egg, and quickly burrows into its host's solid tissues, where it changes into a cysticercus, to go through the same train of changes if devoured by a carnivorous animal. If not so devoured it remains passive, and eventually perishes.

Man is more subject to the tapeworm than to the cysticercus phase of the parasite's life. One of the most common tapeworms met with in man is the *Tænia solium*, which often grows to a length of 7 or more feet. Its head (Fig. 67) is about $\frac{1}{40}$ inch in diameter, and carries four suckers with a double circle of hooklets surrounding a prominence or *rostellum*. This tapeworm grows to its full size in about four months. The ova are spherical, $\frac{1}{1170}$ inch in size. The cysticercus stage of the *Tænia solium* is called the *Cysticercus cellulosæ*, and is most commonly met with in the pig, in which animal it constitutes the affection known as "measles," and measly pork is the chief source of *Tænia solium* in man.

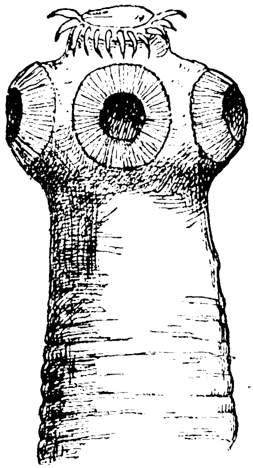

FIG. 67.—Head of *Tænia solium*.

Another tapeworm, somewhat like the preceding, only longer, is that called the *Tænia mediocanellata*. It is not uncommon in man. Its head is $\frac{1}{15}$ inch in diameter, resembles that of solium by having four suckers, but differs from it by not having either hooklets or rostellum. The eggs are oval, being about $\frac{1}{900}$ inch in diameter. Its cysticercus is called the *Cysticercus bovis*, because it occurs in the flesh of cattle; and the practice of eating underdone or raw beef is the chief source of the media-canellata tapeworm in man.

A tapeworm which is very common in Russia, Poland, Sweden, and Switzerland is that known as the *Bothriocephalus latus*. It is a very long tapeworm, often reaching 30 feet in length. Its head (Fig. 68) is ovoid, $\frac{1}{10}$ inch long, and marked by two longitudinal furrows or suckers, but without hooklets. Its eggs are oval, about $\frac{1}{870}$ inch in size, and fitted with a lid at one end. Its embryo is a ciliated organism found in river-water. Its cysticercus is supposed to be found only in fish, more particularly the pike.

Man is occasionally affected with a dangerous parasite under the name of *hydatid* disease. This commonly affects the

liver, but may occur elsewhere. It is really the cysticercus stage of a tapeworm peculiar to the dog and wolf, and called the

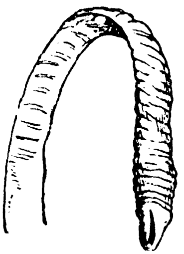

FIG. 68.—Head of *Bothriocephalus latus.*

Tænia echinococcus. The head of this tapeworm is like that of the *Tænia solium*, only that it is but $\frac{1}{100}$ inch in width. The tapeworm is short, having, as a rule, but four segments, and the last segment only has reproductive organs. The echinococcus cysticercus in man differs from all other similar cysts, in increasing indefinitely in size and forms, within itself, secondary cysts, some of which again enlarge, and form, by a process of budding, new cysts within themselves. Not only man, but many animals, are at times affected with hydatid disease, in whom the echinococcus cysts are often spoken of as "bladder worms." It is not difficult to understand how cattle become infected; for the proglottides and eggs of the echinococcus tapeworm, voided so constantly, and in such large numbers by the dog, readily find access on to straw, grass, or even water, and with those articles of food and drink are consumed by the oxen. In the case of man, possibly the sequence of events is not much different. As with cattle, both proglottides and eggs of the tapeworm from the dog may in many ways be carried in food, especially uncooked vegetables, such as lettuces, or on the hands to the mouth, and thus reach the intestine. Probably, a greater risk of infection lies in the habit which dogs have of licking the hands and faces of their masters, and that often after they have been smelling and snuffing about other dogs. These are considerations which should prevent our too familiar association with dogs, more particularly to avoid their licking us, and frequenting dwelling-rooms or kitchens, to say nothing of keeping them clean, and that their excrement is not allowed to remain about. Moreover, full precautions should be taken to prevent infection of dogs by embryos of echinococcus, as may occur in slaughter-houses, where the so-called bladder worms, or echinococcus cysts from slaughtered and infected animals, are often carelessly thrown down. It is needless to say that dogs eating such echinococcus bladders would soon develop them into sexually mature echinococcus tapeworms. It is with a view to avoiding such possible contingencies as the foregoing that the model bye-laws enact that "No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting, or otherwise."

Although the life-history of these various parasites is but imperfectly known, yet the remarkable facts, of which we have reliable knowledge, distinctly point to the great part which water plays in their diffusion to man, and the importance of avoiding all risks of infection by securing a good and pure water-supply; at the same time similar precautions are needed to see that all food is properly prepared and cooked before being eaten.

CHAPTER X.

CLIMATE AND WEATHER.

OUR term climate is derived from the Greek word κλίμα, a slope, and probably had its origin in the idea that the diversities of the qualities and conditions of our atmosphere varied according to the bending or sloping of the earth's surface from the equator to the poles.

The simplest plan of classifying climates is based upon geographical limits, and largely according to latitude. This at best is imperfect unless allowance be made for the influence of warm or cold sea currents, nearness or distance of mountain ranges, and large ocean areas. These latter in particular greatly affect rainfall and exposure to winds. Allowing for these modifying influences, and based upon the principle or limits of latitude, a commonly accepted classification of climates is as follows:—

Warm Climates.—These include what are called tropical and subtropical climates, marked by high temperature, heavy rainfall, and more or less well-defined dry and wet seasons. Such climates are usually met with in places lying between the equator and 35° of latitude north or south of it. Though possibly all the diseases usually attributed to the influence of warm climates are not rightly so, still they are peculiarly apt to be associated with such affections as heat-stroke, yellow fever, cholera, dengue, liver abscess, dysentery, small-pox, and various forms of malarial fever, while scarlet fever and measles are comparatively rare.

Temperate Climates.—These have a mean temperature of

60° F., often with great extremes: four well-defined seasons, usually most rainy during autumn and winter, and the geographical limits of from 35° to 50° of latitude.

Cold Climates, or those belonging to regions situated between 50° of latitude and the poles. In them the summer is short, often lasting but a few weeks, while the winter is long. Snow is extensive, but of rain there is little or none. The diseases of temperate climates are mainly those of everyday English life; while in the cold climates scurvy and scrofula are the principal affections which can be directly attributed to climate. The former arising from a deficient supply of fruit and vegetables, and the latter from the overcrowding and general poorness of living which prevails. Just as diseases of warm or hot climates have an affinity for the abdominal organs, so have the diseases of temperate and cold climates an affinity for the thoracic organs.

Mountain Climates.—These are peculiar, being marked by extremes of temperature, great clearness and rarefaction of the atmosphere, and lessened atmospheric pressure. Mountain climates are peculiarly favourable to those having imperfect chest development, with hereditary or other tendencies to consumption; but are unsuitable for those troubled with chronic bronchitis or acute diseases of the lungs, kidney, liver, or brain. The peculiar effects of mountain climates appear to be due to the increased aeration of the blood which takes place during the act of breathing mountain air, and as a result of this, these climates are best suited for those capable of taking abundant exercise, and distinctly hurtful to the aged and very feeble.

Marine Climates are those prevailing upon islands, capes, and sea coasts, in which the temperature is remarkably equal, rarely reaching extremes, and in which, owing to the increased moisture and rainfall, a certain softness of atmosphere is experienced. The climates of Great Britain, Norway, and Iceland may be taken as types of these so-called marine climates. The principal diseases which appear to be in any way peculiar to marine climates are rheumatism and the various affections of the lungs and air passages, the greater part of which may be due to the dampness and constant weather changes which are so characteristic of these climates.

The multitudinous effects which climates have upon health have long been recognized, and have constituted one of the most difficult questions which nations and governments have had to consider in regard to schemes of colonization, location of communities, and the movement of armies. So great is the influence of climatic conditions upon health, that it is probable that many of the divisions of the human race owe their principal and

essential characters to its continuous action through successive generations. Note the difference between an Englishman and an Italian, or between a German and a native of India. These effects of climate appear really to be the expression or result of the influences of all the various elements or factors and conditions which go together to make a climate. Such are temperature and sunshine, rainfall and moisture, wind and atmospheric pressure or density. The systematic observation and study of these various phenomena constitute the science of meteorology.

Temperature.—One of the most remarkable facts in connection with man is that when in health he is able to maintain his normal or standard body heat of 98° to 99° F under the most extreme and opposite climatic conditions. This, of course, is not always the case, for at times both extreme cold and heat profoundly affect man's physiological condition. Thus, prolonged exposure to extreme cold causes excessive contraction of the smaller blood-vessels, resulting in so great a shutting off of the blood supply to the extremities that they become gangrenous or frost-bitten. At the same time, if the exposure be very prolonged, the body loses all power of reaction, lassitude sets in, followed by deep sleep, usually ending in insensibility and death. More rarely the languid state is replaced by one of delirium not unlike intoxication.

Except perhaps in the tropics, the general effect of direct sun's rays on the body is beneficial; but prolonged exposure to great heat, whether in the sun or in the shade, is accompanied by pronounced physiological disturbance. Some experiments go to show that the body heat itself is increased $\frac{1}{20}$ degree for each degree (Fahrenheit) rise in the air's temperature, while the respirations of those living in hot countries, though at first (some six months) increased, are afterwards so much lessened in frequency that the entire respiratory function is reduced by about $18\frac{1}{2}$ per cent. Much of this lessened respiratory function in hot climates is said to be due to the fact that with a high temperature the quantity of oxygen present in the air is diminished. Thus, a cubic foot of dry air at 32° F. weighs 566·85 grs., which, neglecting the slight amount of carbon dioxide present, gives in that cubic foot of air 436·5 grs. of nitrogen and 130·35 grs. of oxygen. Assuming that a man at rest breathes 16·6 cubic feet of air per hour into his lungs, he will at 32° F. receive 2164·2 grs. of oxygen per hour. At a temperature of 100° F. (which is not unusual in the tropics) a cubic foot of dry air weighs 498 grs., and is made up by weight of 383·5 grs. of nitrogen and 114·5 grs. of oxygen. Therefore in an hour, breathing as before, the man would receive 1901 grs. of oxygen, or nearly 12 per cent. less

than he would breathe in at the lower temperature. The action of the skin is increased in hot countries by as much as 24 per cent., but the water exhaled by the breath and passed off by the kidneys is proportionately reduced. In hot climates, the general functions of the whole body become impaired, notably the nervous system and digestive organs, which, from being the seat of more or less increased action, are peculiarly liable to become congested and enlarged. The essential requirements for the bearing of great heat by the body is the maintenance of abundant perspiration; the moment this fails the heat equilibrium is disturbed, and the body heat rises rapidly, accompanied sooner or later by insensibility and death from heat-stroke.

Owing to our senses being insufficiently acute to measure slight changes in temperature, we have to make use, for this purpose, of instruments, called thermometers, which indicate, by means of the expansion or contraction of bodies under heat, its varying degrees of intensity. Liquids are the bodies best suited for this purpose in the construction of thermometers—the expansion of gases being too great, and that of solids too small. Of liquids, mercury and alcohol are practically the only ones used; the former because it boils only at an extremely high temperature, and freezes at a very low one, and the latter because at atmospheric pressure it does not solidify at the greatest known cold. For these reasons, mercury is used for recording high degrees of heat, and alcohol for low temperatures, the alcohol when so used being generally coloured. Although there are many varieties of thermometers, they can practically be divided into three kinds, namely, the ordinary, the registering, and the recording.

Ordinary thermometers consist of a capillary glass tube, at the end of which is blown a bulb or reservoir. The manufacture of a thermometer, to ensure accuracy, is one of great delicacy and care; in the first place, the tube must be divided into parts of equal capacity, or *calibrated*, as it is called; next, it must be filled and finally graduated for the construction of the scale. Just as a foot-rule is divided into a number of equal divisions called inches for comparison of length, so is a thermometer marked into a number of parts of equal capacity for the comparison of temperatures, called degrees. Sometimes the scale is marked upon the thermometer stand, but in the best and more accurate ones it is marked on the actual stem.

Since ice constantly melts at the same temperature and distilled water under an atmospheric pressure of 29·92 inches, and in a metal vessel always boils at the same temperature, these two temperatures are taken as the limits of the scale, and

the interval between them is taken as the unit for comparing temperatures, just as a foot or yard are taken for comparing lengths. The melting-point of ice or first fixed limit is usually called zero, and the other fixed limit the boiling-point. On the continent of Europe, the scale of a thermometer is divided into 100 parts or so-called Centigrade. This division is really the simplest, and now generally used in this country in connection with all scientific work. In this scale, the zero or freezing-point is at 0 degrees, while the boiling-point is at 100 degrees. The degrees are usually designated by a small cypher placed a little above on the right of the number, thus $20°$, while to indicate temperatures below zero, the minus sign is placed before, thus $-10°$, or ten degrees below freezing.

Another scale, known as Réaumur's, is used in Russia and some other parts of the Continent; in it the fixed points are the same as in the Centigrade: but the interval between them is divided into 80 instead of 100 parts; that is to say, 80 degrees Réaumur equal 100 degrees Centigrade, or 1 degree Réaumur is $\frac{5}{4}$ of a degree Centigrade, or 1 degree Centigrade is $\frac{4}{5}$ of a degree Réaumur. Consequently, to correct Réaumur degrees into Centigrade ones it is necessary to multiply them by $\frac{5}{4}$. Similarly, Centigrade degrees are converted into those of Réaumur by multiplying them by $\frac{4}{5}$.

In England and America, for general use, the thermometric scale invented by Fahrenheit is still employed. In this scale the higher fixed point is, like that in the Centigrade and Réaumur scales, that of boiling water; but the lower fixed point, or zero, is not the temperature of melting ice, but that obtained by mixing equal parts of snow and sal ammoniac, and the interval between the two is divided into 212 parts or degrees. The zero temperature on this scale is lower than that of melting ice, with the result that when a Fahrenheit scale thermometer is placed in melting ice, it stands at 32 degrees, and, therefore, 100 degrees on the Centigrade scale and 80 on the Réaumur equal 212 less 32, or 180 degrees on the Fahrenheit, or 1 degree Fahrenheit equals $\frac{5}{9}$ of a degree Centigrade, and $\frac{4}{9}$ of a degree Réaumur For the conversion of any given number of degrees Fahrenheit into Centigrade or Réaumur degrees, the number 32 must be first subtracted in order that the degrees may count for the same part of the scale, and the result then multiplied by the relative value of the two degrees. Conversely, Centigrade and Réaumur degrees may be converted into Fahrenheit by adding 32 after multiplying by the ratio value. Thus, by the use of the following formulas—

$$\tfrac{9}{5}\text{C.} + 32 = \text{F.} \qquad \tfrac{9}{4}\text{R.} + 32 = \text{F.}$$
$$(\text{F.} - 32)\tfrac{5}{9} = \text{C.} \qquad (\text{F.} - 32)\tfrac{4}{9} = \text{R.}$$

we can show that 20° F. equals $-6°{\cdot}6$ C., or $-5°{\cdot}4$ R., and that 20° C. equals 68° F., and 20° R. equals 77° F.

A good mercury thermometer should answer to the following tests. When completely immersed in melting ice, the top of the mercury should exactly indicate zero or 32°, according as to whether the scale be Centigrade and Réaumur or Fahrenheit; and when suspended in the steam of water boiling in a metal vessel with the barometer at 29·92 inches, the mercury should be stationary at either 100° or 212° according to the kind of scale. The value of the degrees should be uniform, as shown by a detached piece of mercury occupying an equal number of degrees in ali parts of the tube.

Owing to the temperature constantly varying, the actual reading observed has but a limited value, so that registering thermometers are required; of these there are two kinds in common use, namely, those known as minimum and maximum thermometers.

The minimum thermometer or instrument for registering the lowest temperature during a given period of time, is sometimes known as Rutherford's minimum. In principle it is very simple, the bulb and part of the stem being filled with coloured alcohol in which a little glass or metal index is placed. When the temperature falls, and the alcohol contracts, the capillary attraction of the liquid draws the index back with it towards the bulb; but when the temperature rises again, the alcohol passes the index, and leaves the extremity of it farthest from the bulb at the lowest temperature reached. The instrument, after having been read, is readily set up by partially inverting it and letting the index fall to the top of the spirit column; it is then hung up in a horizontal position. Occasionally air bubbles appear in the alcohol and fix the index, while at other times some of the alcohol volatilizes and condenses at the top of the tube. Both these faults can be easily cured by holding the thermometer bulb downwards and swinging it rapidly round; this will usually cause the air bubbles to disperse, and displace any condensed alcohol from the top of the tube. If, by chance, as the result of this procedure, the index be thrown into the bulb, a little tapping and patience will bring it out again.

Of maximum thermometers, or those registering the highest degrees of heat during any given time, there are two in very general use, namely, Negretti's and Phillips's. Both these instruments have mercurial columns, a detached portion of which

serves as an index for the highest temperature reached. In Negretti's, the detachment is made by means of a slight contraction of the tube, which, while allowing the expanding mercury to pass when the temperature is rising, is sufficient to overcome the natural cohesion of the metal, when contracting, to prevent it drawing it back on cooling. In Phillips's, the detached portion of the mercurial column is separated from the rest by a bubble of air. Both these instruments are placed horizontally, and both can be re-set by lowering the bulb, and then either gently tapping or swinging the thermometer.

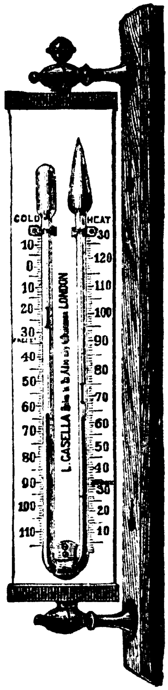

FIG. 69.—Six's thermometer.

Previous to the invention of these minimum and maximum thermometers, a registering instrument known as Six's thermometer (Fig. 69), from the name of its inventor, was much used, and is so now. The tube of the instrument is long and U-shaped. One limb constitutes the cold tube, and has at its extremity a bulb, while the other limb is the heat tube, having at its top or end a small chamber in which is confined some air. The middle portion of the tube contains mercury extending round the bend and part of the way up each limb. The bulb and both tubes or limbs above the mercury contain alcohol. Inside the alcohol are two steel indices, one being in the cold tube and the other in the heat tube. These are readily set, or caused to rest gently upon either column of mercury by moving them by means of a magnet. This being done, if the temperature rise, the alcohol in the bulb will expand and push down the mercury in the cold leg, but raise that in the heat leg, and by so doing drive up the index in it until the temperature ceases to rise, when the point of maximum heat will be indicated by the lower end of that index. On a fall of temperature precisely the reverse will happen, for then the spirit within the bulb will contract, and the pressure in the air chamber at the top of the heat leg will force the mercury down in it, but up in the cold limb, while the cold index will continue to go up so long as the temperature continues to fall. Of course the scales read downwards on the cold leg and upwards in the heat one, and in each the lower end of the index shows respectively the lowest and highest temperature reached since the

instrument was last set. The presence of the air chamber makes a Six's thermometer unsuited for travelling, and necessitates the vertical position.

Of recording thermometers, the cheapest are those of Cripps or Richard. The bulb is a large curved flattened tube, filled with a liquid which tends to straighten with an increase of heat, and this being connected with a long lever in such a manner as to rise with increase of temperature and to fall with decrease, marks a tracing line upon a revolving cylinder. This cylinder depends upon a clockwork arrangement, and can be wound up, started, and left untouched for given periods of time, at the end of which records of temperature will be found for every instant during the period. As the curvature of the tube and the spring mechanism are apt to alter, these instruments need to be corrected and compared periodically with an accurate mercurial thermometer.

In all efforts to compare climates or temperatures, it is not only necessary to have accurate thermometers, but also to place them so far as possible under similar conditions; for this purpose uniformity of exposure is obtained by placing or exposing thermometers in certain standard screens. The thermometers already described are invariably kept in the shade, and carefully protected from all direct rays of the sun and effects of reflected or radiated heat from walls and buildings. Owing to this fact, these instruments are sometimes spoken of as shade thermometers in contradistinction to others which will be described later on, and known as sun thermometers. The screen or arrangement for shade thermometers is a hut or box known as Stevenson's screen. It is made of stout boards, with a ridge roof and louvred sides open below, and standing some 4 feet off the ground on four legs. It is placed where it will be freely exposed to the movements of the air, and at least 20 feet away from any house or building. All thermometers should be read once daily, say 9 a.m., when the highest and the lowest temperatures of the previous twenty-four hours will be recorded.

The mean temperature of the day may be obtained by taking a single reading at 9 p.m., or by taking the mean of two readings at 9 a.m. and 9 p.m., or by taking the mean of the maximum and minimum recorded temperatures; this is usually correct for winter, but in summer may be as much as 2° too high.

The only true mean can be obtained by taking a mean of hourly readings. The weekly, monthly, and annual means are derived from daily means. As a rule, the lowest temperature is recorded at 3 a.m. and the highest at 2 p.m., but of course proximity to the sea or elevation and influence of latitude considerably affect these observations.

Some idea of the intensity of the sun's heat is obtained by means of what are called *solar radiation thermometers* or maximum thermometers placed direct in the sun's rays. In order to avoid loss of heat by reflection from the bright glass surface of the bulb, this and one inch of the stem is coated with lamp-black, and this again, to protect it from being washed off by rain, is placed in a glass case out of which air has been pumped to make it a vacuum. Unfortunately, the presence of the outer glass covering largely interferes with the cooling influence of wind, which materially affects the distribution of heat by the sun in Nature. Notwithstanding this theoretical defect, the blackened bulb maximum thermometer *in vacuo* is the best instrument we have for measuring the amount of heat given out or radiated by the sun. The instrument is exposed freely to the sun and air by fixing it horizontally 4 feet above the ground, well away from trees or walls, and with its bulb, in this country, pointing south-east. The heat recorded by such an instrument will be the temperature at which an equilibrium or balance is established between the heat produced by the direct rays of the sun on the bulb, and the cooling caused by radiation or loss of heat from the bulb to the glass jacket or covering ; this latter, of course, will have practically the same temperature as that of the air. It follows, therefore, that the excess of the temperature of the black bulb over that of the outer air, as registered by the maximum shade thermometer, will be an approximate measure of the power of the actual sun's rays, or, in other words, the power of the sun's radiation of heat. This is but a crude measure of the actual heat emitted by or derived from the sun's rays. The only accurate method is by a special instrument called a "bolometer." In principle the bolometer is simple : it depends on the fact that the electrical resistance of a metal is increased by heat. Two strips of metal are connected with a galvanometer and one of them is exposed to the sun's rays passing through a narrow slit. When heated by the sun's rays, the resistance of this piece of metal is increased and the galvanometer needle moves. So sensitive is this instrument that differences of temperature of less than one hundred millionth of a degree can be detected. After allowing for atmospheric absorption it is estimated that the solar constant is 30 calories, or the earth receives hourly enough heat to melt a circular disc of ice nine-tenths of an inch thick and nearly 8000 miles in diameter. In a year, the solar rays would melt a disc 657 feet thick. Owing to varying atmospheric conditions the amount of solar heat varies at different points on the earth's surface.

Not only is there a constant gain of heat by the earth from the sun, but there is also a more or less constant loss of heat

from the earth and from all objects on it. This loss of heat is spoken of as *terrestrial radiation*, and is very much greater when the sky is clear and the air dry than when overcast with clouds, or when much moisture is present in the atmosphere. It is owing to the comparative rapidity with which soil covered with grass and vegetation radiates heat into space that the air over grass-plots and lawns is colder than that in immediate contact with or over bare flower-beds and gravel-walks. This loss of heat from

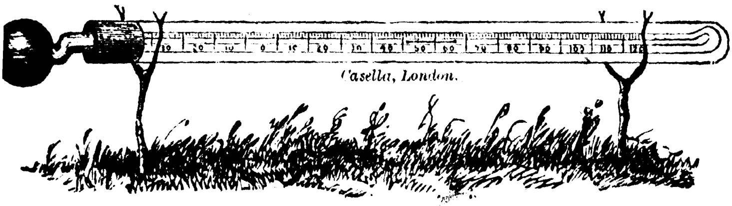

FIG. 70.—Minimum thermometer on grass for recording terrestrial radiation.

the earth is most marked where the disturbing influence of air currents is least, hence it is usual to place a thermometer intended to measure radiation upon the ground. The amount of the loss of heat by radiation is determined by placing a minimum thermometer, as already described, on short supports some 4 inches off the ground on a plot of grass (Fig. 70). The difference or defect of this minimum temperature below that of the air minimum in the shade is taken as the amount of terrestrial radiation.

Sunshine.—The duration of the sunshine is a very important factor in all climates, and the extent of this duration is recorded by either what is called Whipple-Casella's apparatus or by Jordan's. The former is mainly a glass sphere so mounted that when the sun shines its rays are focussed as by a lens upon a strip of cardboard, with the result that a burnt track or hole is left for such periods of time as the sun shines. The cardboard is so placed in the instrument that definite sections of it correspond to periods of time and hours. Jordan's instrument is, strictly speaking, rather a recorder of sunlight than of sunshine. It consists of a circular box in which some sensitive photographic paper is placed, and the sunlight entering through a slit leaves a varying record of its duration and intensity. The paper can be readily "fixed" by washing in clean salt water.

Rainfall.—No factors have more influence upon the suitability or unsuitability of the climate of any particular country than the amounts of its humidity and rainfall. The *physical cause* of rain

is the sudden chilling of comparatively warm air, more or less laden with moisture, either by its ascent into the upper and colder regions of the atmosphere, or by its impact against cold mountain slopes, or with the colder surface of the ground. The former cause is more potent in the summer, the latter in winter. It was formerly supposed that rain was largely caused by the mixture of masses of air of different temperatures. But, even supposing that any such admixture did take place, a comparison between the units of heat set free by condensation and the weight of aqueous vapour per cubic foot of air at any two given temperatures—one high, the other low—shows that the mixture of volumes of air cannot be very effective in causing precipitation (Hann). In fact, the latent heat set free in the process of condensation largely prevents that fall of temperature which is assumed to take place and to cause a rainfall.

The amount of rainfall is measured by an instrument called a rain-gauge, which, in its simplest form, is a copper funnel leading to a can or other receiving vessel (Fig. 71). In this country the funnel is usually circular and 8 inches in diameter, so that its area in square inches is accurately known. Having entered the funnel, the rain passes down a long and narrow tube, which at its end is curled upward to check evaporation, into a metal-collecting vessel. The rain, having been collected in the receiver, is measured in a graduated glass vessel, the divisions of which correspond to half-inches and tenths. The measuring vessel is divided proportionately to the area of the gauge, the diameter of which should always be some simple unit, like 5 or 8 inches, so that if the original measure get broken, a new one can be readily improvised and graduated. Thus, take an 8-inch gauge, the diameter being 8 inches, its receiving area is 50·26 square inches; therefore, 1 inch of rainfall, or rain 1 inch deep over a town, would deposit in that particular rain-gauge 50·26 cubic inches of water, or 29½ fluid ozs. Therefore, if 14¾ fluid ozs. of water be poured into the proposed measuring glass, and the vessel be marked with a line at its level, that line will represent

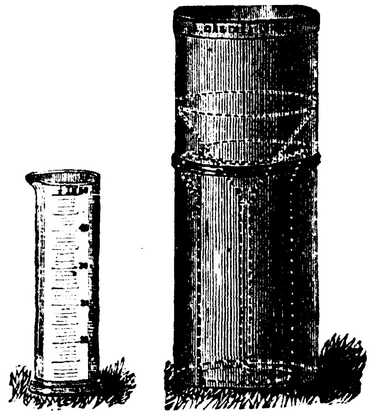

FIG. 71.—Rain-gauge and measuring-glass.

the graduation of $\frac{1}{5}$ inch of rain; subdivision markings are similarly made for tenths and hundredths of an inch.

In the absence of a properly constructed rain-gauge, the amount of rainfall can be readily measured in any receiving vessel, provided its receiving area is known, by measuring the volume collected in either fluid ounces or cubic centimetres, and making the calculation on the basis of the facts that 1 fluid oz. equals 1·728 cubic inch, and that 1 c.c. is 0·061 cubic inch. Thus—

$$\frac{\text{cubic centimetres of rain collected} \times 0·061}{\text{area of receiving vessel in square inches}} = \text{inches of rain,}$$

$$\text{or,} \quad \frac{\text{fluid ounces of rain collected} \times 1·728}{\text{area of receiving vessel in square inches}} = \text{inches of rain.}$$

More rain is collected on the ground than on the top of a building, or on a stand at a height above the ground. For this reason the best place for a rain-gauge is on the ground in a well-exposed position, with the rim about one foot above the earth. A rain-gauge should never be placed upon a house-roof, unless, as in towns, no sufficiently open space is available. The spot on which a rain-gauge is exposed should be clear of all objects whose height is greater than their distance from the gauge. Rain should not be collected in the measuring glass, as it is liable to break, especially during frosts. Snow or hail can be measured by thawing the quantity collected and measuring the water which results. To avoid snow being blown out of the gauge, the upper edge of the funnel is usually fitted with a vertical rim about 6 inches in depth, and ground to a fine edge on the top.

The amount of rain which falls varies, of course, very much with the place; but in determining the average fall at any station, it is necessary to deal with observations extending over long periods. In England and Wales, the average rainfall each year is 33·76 inches; in Scotland, 46·56 inches; in Ireland, 38·54 inches. The average annual rainfall for the United Kingdom is 37·30 inches; for Great Britain, 36·69 inches. On the east coast of England not much more than 20 inches of rain falls in a year, while on the west coasts of both Scotland and Ireland it averages as much as 60 or 80 inches; in some parts of Cumberland as much as 150 inches a-year have been known to fall. It is very rarely that more than 1 inch of rain falls anywhere in Great Britain in one day; though occasionally as much as 5 inches have been known to fall. For furnishing meteorological returns, a minimum record of 0·01 inch is considered as characteristic of a rainy day in this country.

Humidity.—The question of the amount of moisture in the air is somewhat complicated, and is usually spoken of as the degree of humidity. It was explained in an earlier chapter that water is constantly evaporating into the air, and that the amount of water or moisture which the air can hold or retain is constantly varying with its temperature. Thus at 32° F. a cubic foot of dry air can only take up 2·10 grs. of water, while at 100° F. it can take up as much as 19·84 grs. When air is so full of moisture that it can contain no more, it is said to be saturated. In this country the air upon an average contains about three-fourths of the amount of water needed to saturate it —that is, it has an humidity of about 75 per cent.; but if the air containing this amount of moisture be cooled down, it will reach a degree of heat at which that same amount of moisture will suffice to saturate it, and if cooled still more, it will reach a temperature insufficient to retain that moisture, with the result that it must part with some of it, the amount so parted with being precipitated or deposited as rain, snow, mist, or dew. For instance, 100 cubic feet of air three parts saturated with moisture at a temperature of 70° F. would hold 600 grs. of water; if for some cause or other the temperature of that 100 cubic feet of air were reduced to 61° F., that volume of air would become quite saturated, because at that temperature it could only hold 600 grs.; and if the temperature were still further reduced, say to 56° F., it could only retain 500 grs. of moisture; therefore the difference between 600 and 500 grs., or 100 grs. of water, would be released or deposited as mist, dew, or rain.

It has been pointed out by some observers that occasionally, in perfectly pure air, a pressure of vapour may be maintained greater than that corresponding to the temperature of saturation (Aitken). In fact, that condensation will not in general begin unless some nucleus is present to which the particles of water can attach themselves. It is on the presence of solid particles of dust in the air that the formation of mists and fogs depends, the precise degree of mist or fog depending on the amount of dust present, and on the size and constitution of the particles. When the number of dust particles is large or their size considerable, and the quantity of vapour condensed is small, we get the phenomenon of a town, or so-called dry fog. The condensation of water upon invisible particles so increases their size as to make them visible. Often in the case of town fogs their obviousness is not so much due to the action of the moisture condensed on the particles as to the excessive size and quantity of the particles themselves. What are known as sea fogs probably occur in air which is comparatively dry, because the dust in their case

consists largely of salt grains derived from spray or surf, and which have a great affinity for moisture. If the quantity of condensed moisture is large, or the amount of dust and other solid nuclei small, we get what is called a mist, and it is merely a question of the degree of the moisture present which determines where the mist ends and actual rain begins.

The formation of dew is precisely analogous; in this case the solid substance on which the moisture is precipitated or condensed is the surface of the ground, or a blade of grass, and not solid nuclei like soot or dust floating about in the air, as in the formation of fogs. Owing to the rapidity with which the earth, under certain circumstances, loses heat by radiation, as, for instance, on a fine clear night, the strata of air containing

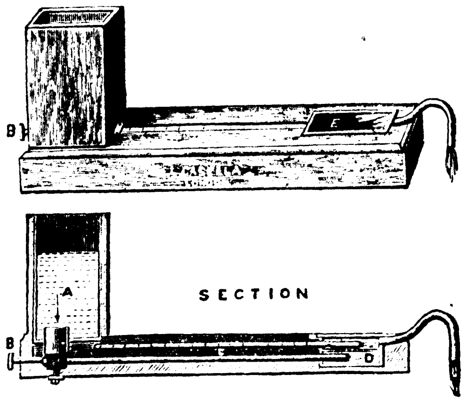

FIG. 72.—Dine's hygrometer.

moisture which are in contact with the cooling earth, themselves become reduced so much in temperature that they are no longer able to retain their water vapour, but actually lose it by condensation upon the ground, where it constitutes what we call dew. The particular temperature at which air saturated or loaded with moisture deposits its water is called the *dew-point*. It is from the determination of this dew-point that the weight of water present in the air (or, in other words, the percentage of saturation of the air for the existing temperature) is calculated. This, of course, expresses the degree of humidity.

For the determination of the temperature of the dew-point, certain instruments called *hygrometers* are used. Of these there have been many varieties. A very ingenious instrument of this kind is that known as Dine's hygrometer (Fig. 72). Some cold

water is put into the cup A, and allowed to flow through the channel D, whence it rises through a perforated diaphragm into a space above, in which rests the bulb of a thermometer; the space itself being rendered water-tight by a thin cover of blackened glass, E. On turning the tap B, the water flows through the chamber, and so cools the glass cover down until a thin film of dew or moisture is deposited on it from the contiguous air; the precise temperature of this dew-point, or moment of dew, being deposited on the black glass is read off on the thermometer C, and recorded as that of the dew-point.

Another instrument, known as Daniel's hygrometer (Fig. 73), consists of a bent tube with a globe at each end, and is partly

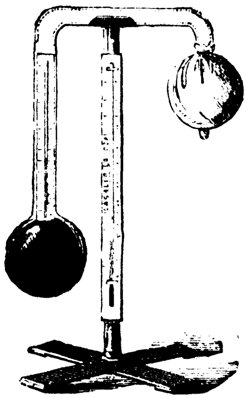

FIG. 73.—Daniel's hygrometer.

filled with ether, the rest of the space in the tube being filled with the ether vapour, all the air having been expelled. One globe is made of blackened glass, and contains a thermometer, while the other is covered with muslin. Before using the instrument, the ether is made to pass into the blackened globe containing the thermometer, while the muslin surrounding the second globe is moistened with ether. This ether rapidly evaporates, causing a condensation of some of the ether vapour inside the tube; this in its turn produces an evaporation of the ether in the blackened bulb. Now, whenever evaporation occurs, there is absorption of heat, so that the black bulb gradually becomes colder and colder, and the moment is soon reached when the air in contact with it begins to deposit dew on its surface. So soon as this happens, the temperature shown by the contained thermometer is read off and recorded as the dew-point.

The most common form of hygrometer now employed in this country is that known as the dry-and-wet bulb thermometer (Fig. 74). It really consists of two ordinary thermometers mounted on a frame side by side. One of these has its bulb covered with muslin, and kept constantly moist by being connected with a small vessel containing distilled water, by means of the capillary action of a piece of cotton wick, which has been previously well freed from grease by being boiled in ether. The dry bulb gives, of course, the temperature of the air, while the wet one, in consequence of the evaporation constantly going on from its surface, gives a lower reading. The difference between the two temperatures recorded indicates the rapidity with which evaporation is proceeding, and, moreover, since evaporation is faster the drier the air, the indication of the degree of evaporation is a measure of the dryness or moistness (otherwise humidity of the air). If the air be saturated with moisture, of course no evaporation is going on, and the two thermometers will record the same temperature. In frosty weather, frequently the muslin covering and the water in the vessel will freeze, with the result that evaporation will not take place. In such case it suffices to brush the frozen muslin over with a brush dipped in cold water and allow this to freeze; at such time evaporation will be going on from the ice surface, so that it will be equivalent to its having a damp but unfrozen bulb.

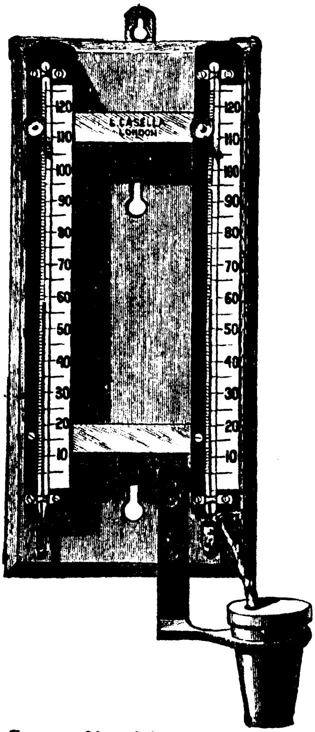

FIG. 74.—Mason's hygrometer, or the dry-and-wet-bulb thermometer.

The calculation of the dew-point from the readings of the dry and wet bulbs can be roughly made by taking it to be as much below the wet-bulb reading as that is itself below the dry; but for greater accuracy use must be made of certain factors which have been worked out by Glaisher, and given in the following table:—

Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.	Reading of the dry-bulb therm. F.	Factor.
10°	8·78	33°	3·01	56°	1·94	79°	1·69
11°	8·78	34°	2·77	57°	1·92	80°	1·68
12°	8·78	35°	2·60	58°	1·90	81°	1·68
13°	8·77	36°	2·50	59°	1·89	82°	1·67
14°	8·76	37°	2·42	60°	1·88	83°	1·67
15°	8·75	38°	2·36	61°	1·87	84°	1·66
16°	8·70	39°	2·32	62°	1·86	85°	1·65
17°	8·62	40°	2·29	63°	1·85	86°	1·65
18°	8·50	41°	2·26	64°	1·83	87°	1·64
19°	8·34	42°	2·23	65°	1·82	88°	1·64
20°	8·14	43°	2·20	66°	1·81	89°	1·63
21°	7·88	44°	2·18	67°	1·80	90°	1·63
22°	7·60	45°	2·16	68°	1·79	91°	1·62
23°	7·28	46°	2·14	69°	1·78	92°	1·62
24°	6·92	47°	2·12	70°	1·77	93°	1·61
25°	6·53	48°	2·10	71°	1·76	94°	1·60
26°	6·08	49°	2·08	72°	1·75	95°	1·60
27°	5·61	50°	2·06	73°	1·74	96°	1·59
28°	5·12	51°	2·04	74°	1·73	97°	1·59
29°	4·63	52°	2·02	75°	1·72	98°	1·58
30°	4·15	53°	2·00	76°	1·71	99°	1·58
31°	3·60	54°	1·98	77°	1·70	100°	1·57
32°	3·32	55°	1·96	78°	1·69		

To use the table, the rule is to multiply the difference between the readings of the two bulbs by the factor corresponding to the reading of the dry bulb, and subtract the product from the dry bulb; the result is the temperature of the dew-point. Thus, say the dry bulb is 62°, and the wet bulb is 56°; their difference is 6, and this, multiplied by the factor 1·86, or that corresponding to the dry-bulb reading, gives 11·16, and this, taken from 62°, yields 50°·84 as the temperature of the dew-point.

Having obtained the temperature of the dew-point, the *relative humidity* is determined by further reference to a table, like the following, in which the weight of a cubic foot of vapour constituting saturation, at various temperatures is given:—

Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.
0°	0·55	26°	1·68	51°	4·24	76°	9·69
1°	0·57	27°	1·75	52°	4·39	77°	9·99
2°	0·59	28°	1·82	53°	4·55	78°	10·31
3°	0·62	29°	1·89	54°	4·71	79°	10·64
4°	0·65	30°	1·97	55°	4·87	80°	10·98
5°	0·68	31°	2·05	56°	5·04	81°	11·32
6°	0·71	32°	2·13	57°	5·21	82°	11·67
7°	0·74	33°	2·21	58°	5·39	83°	12·03
8°	0·77	34°	2·30	59°	5·58	84°	12·40
9°	0·80	35°	2·39	60°	5·77	85°	12·78
10°	0·84	36°	2·48	61°	5·97	86°	13·17
11°	0·88	37°	2·57	62°	6·17	87°	13·57
12°	0·92	38°	2·66	63°	6·38	88°	13·98
13°	0·96	39°	2·76	64°	6·59	89°	14·41
14°	1·00	40°	2·86	65°	6·81	90°	14·85
15°	1·04	41°	2·97	66°	7·04	91°	15·29
16°	1·09	42°	3·08	67°	7·27	92°	15·74
17°	1·14	43°	3·20	68°	7·51	93°	16·21
18°	1·19	44°	3·32	69°	7·76	94°	16·69
19°	1·24	45°	3·44	70°	8·01	95°	17·18
20°	1·30	46°	3·56	71°	8·27	96°	17·68
21°	1·36	47°	3·69	72°	8·54	97°	18·20
22°	1·42	48°	3·82	73°	8·82	98°	18·73
23°	1·48	49°	3·96	74°	9·10	99°	19·28
24°	1·54	50°	4·10	75°	9·39	100°	19·84
25°	1·61						

It is usual to express saturation by 100, and to calculate the relative humidity or the ratio of the absolute humidity to saturation by dividing the weight of a cubic foot of vapour corresponding to the temperature of the dew-point by that corresponding to the temperature of the air, and multiplying by 100. Thus, taking the same example as given above, in which the dry bulb reads 62°, the wet 56°, and the dew-point is found to be 50°·84, and using the foregoing table, we get the weight of moist vapour per cubic foot corresponding to the dew-point to be 4·21 grs., and this divided by 6·17, or the corresponding vapour weight for the air temperature, gives 0·68, and that multiplied by 100 shows the relative or percentage humidity to be 68.

This percentage saturation of the air is practically an inverse measure of the drying power of the air, and as such has a most important bearing upon climatic conditions, more particularly the degree of radiation from the earth's surface. We are all familiar with the peculiarly unpleasant effects of a hot moist atmosphere,

and with the invigorating influence of dry and crisp air. A saturated atmosphere at from 35° to 50° F. will be found to be intolerably chilly, and although the evaporation may be checked, and this source of heat-loss removed, yet the conduction and radiation due to the vapour in the air will be enormous. A temperature of 50° to 65° F. in a nearly saturated atmosphere seems to be not uncomfortable, as under those conditions an equilibrium seems to be established between the cooling action by conduction and radiation, due to the vapour in the air, and the supply of heat from checked skin evaporation. A saturated atmosphere with a temperature of from 65° to 80° F. becomes oppressive and sultry. Above 80° F., a saturated air becomes most oppressive, and it is doubtful whether life could be long sustained in a saturated atmosphere of 90° to 100° F., as the surplus heat cannot be removed by conduction or radiation, while at the same time the natural effort of the system to produce evaporation is enormously exaggerated. Humidity of the air is very generally supposed to be associated with the spread, or rather prevalence of disease; much moisture in the air certainly favours the continuance of colds, but at the same time appears to relieve bronchitis by assisting expectoration and the general discharge of mucus. Malarial diseases are said never to attain their worst form except the air be saturated with moisture, but on this point the evidence is not very strong.

Evaporation.—How much water is returned to the atmosphere by evaporation from any moist surface, such as that of the earth, is a factor which largely affects climate, but our knowledge regarding it is small, as it is both complicated and regulated by the temperature, and the degree of moisture in the air and winds. In this country, the mean annual evaporation from a square inch of water surface has been calculated to be about 20 inches. Various attempts have been made from time to time to measure the evaporation going on. An approximate idea of its amount can be obtained by exposing a measured volume of water in an open vessel of known area, and deducting from its final volume, after exposure for a given period, the amount of rain which has been known to fall into it during that time.

Winds.—The facts relating to winds are practically limited to those connected with direction, force or pressure, and velocity. As a rule, there is comparatively little trouble in obtaining records as to direction, as, if no vane is convenient, the smoke from a chimney will readily give the information, provided, of course, the observer has a precise idea as to where lies his north or south. A wind vane should be placed perfectly clear of trees, buildings, or anything likely to deflect the course of the wind, and, too, should be kept clean, and oiled to avoid sticking. All wind observations

should be recorded to the nearest point of the compass. To calculate the mean direction, it is usual to give an arbitrary numerical value to each observation, and then to analyze them. Thus, suppose we read to 16 points of the compass, and give a numerical value of 4 to each observation; if the wind be due N., we should give to N. the full value of 4; if the reading were N.W, we should give half the value of the observation, or 2, to N., and the other half to W. If the reading were N.N.W., then N. would get 3, and W. get 1, as their shares of the numerical value of the observation. Suppose we have the following observations of wind direction recorded: S., S.E., E., S.S.E., N.W., W.N.W., N.E., E.N.E., N., N.E. Giving to each observation a numerical value of 4 and deducting the opposite directions from each other, we find the mean direction is six points nearer E. than N. As each point on the compass equals $11^{\circ}\cdot25$, the precise mean direction of the wind for these ten readings is 6 times $11^{\circ}\cdot25$ or $67^{\circ}\cdot5$ from N., which on the compass is a mean direction of E.N.E.

The instruments for the measurement of wind, either as regards its force or pressure and velocity, are called *anemometers*. The earlier forms of these instruments were rectangular plates, whose movements, resisted by either springs or weights, recorded upon a chart by means of a connected pencil the amount of their displacement. In another form, the pressure of the wind is measured by making it blow into the mouth of an open tube kept facing the current by a vane, and noting the influence of the pressure exerted upon a column of water or mercury in a siphon. The later anemometers in use are those known as Robinson's, consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis, which, by means of an endless screw, causes movements to be recorded upon a series of dials in terms of miles and parts of a mile. These instruments are graduated on the principle that, allowing for friction, the cups revolve three times slower than the wind moves; so that if the centres of the cups be 1·12 feet apart, each revolution corresponds to 3·52 feet of movement, or 10·56 feet of actual wind motion, and that 500 rotations of the cups indicate one mile of wind. Owing, however, to the allowance for friction being placed probably too high, and the cup motion being nearer 2 than 3 times slower than the wind, the velocity of wind movement as recorded by many instruments in general use is something like 20 per cent. too high All anemometers to be reliable need to be kept scrupulously clean, well oiled, and placed in a thoroughly open position some 20 feet from the ground.

Various proposals have been made for estimating and

describing roughly the force of the wind. The earliest was that of Admiral Beaufort, who, in 1806, devised a scale having a relation to the pressure of the wind upon the sails of a ship, and the amount of canvas which she could carry.

Attempts have been made to express the wind's force as a pressure of so many pounds to the square foot. From experiments with various kinds of anemometers, Dines calculates the pressure P of the wind in pounds per square foot from the recorded velocity in miles per hour, on the assumption that the pressure equals one two hundredth ($\frac{1}{200}$) of the square of the velocity, or $P = 0{\cdot}005 \times V^2$. According to this formula, a wind blowing with a velocity of 50 miles an hour exercises a pressure of $12\frac{1}{2}$ lbs. on the square foot.

In England, the wind has an average velocity of 8 miles an hour, and rarely exceeds 40. As a rule, at midday the wind blows from sea to land, and from plains to hills, while in the evening the direction will be reversed. In this country, the most prevalent wind throughout the year is the S.W., the next is the W. The N.E. wind is the least prevalent, next the S.E., the E., and the N. The W. and S.W. winds are largely the result of the Gulf Stream, and are both warm and moist, while the E. and N.E. winds which blow from the cold areas of northern Europe and Asia are dry and cold. In all parts of the world there are periodical and variable winds due to local causes, while the permanent winds like the N.E. and S.E. trades take their direction from the rotation of the earth, and are caused by the constant movement of cold air from the poles towards the equator to replace the heated air of the tropics. The trade winds vary their prevalence over any particular area according to the season; but some other winds, such as the S.W. and N.E. monsoons of India, are essentially seasonal. The former is a wet wind, while the latter is in the main dry. The S.W. monsoon, usually commencing in May, is caused by the surface of the whole continent of India getting hotter than the sea, by which its air is rarefied, and rises to be replaced by comparatively cooler air currents laden with moisture blowing in from the Indian Ocean. The monsoon having exhausted itself by the time it reaches the northern limits of India, reverse currents of air begin to form, so that about October the wind blows southward from the N.E., and continues to do so until the same phenomena are started again in the early summer by the increased heat of the land. Among other seasonal winds may be mentioned the hot dry Khamsan wind of Egypt which blows from the desert during the spring; while in the Mediterranean, the Bora and Mistral are two cold dry winds coming from some portion of the Alps, the one being a N.E. wind

affecting chiefly the Adriatic, and the other a N.W. wind blowing powerfully over southern France. On the other hand, the E. or S.E. winds in the Mediterranean, commonly called the Sirocco, are hot, moist, relaxing, and proportionately unpleasant.

Clouds.—Although at present all attempts to estimate the amounts of cloud are unsatisfactory, still continuous efforts are being made to record their extent and conformations. As the outcome of an International Meteorological Conference, held at Munich in 1891, it is now usual to divide clouds into five large groups, namely: (A) clouds existing very high in the air; (B) clouds at a medium height; (C) clouds lying low or near the earth; (D) clouds in ascending currents of air; (E) masses of vapour changing in form. A cloud is nothing more than the condensation of vapour into visible shape, and may occur in either of two ways. Either a layer of the atmosphere is cooled in bulk to near its dew-point, with the result that a stratified mass of cloud of greater or less extent is formed, as the so-called *stratus*, or a body of moist air is intruded into a mass which is cold and dry, resulting in a cloud of a heaped-up or *cumulus* form.

A close analysis of the various shapes or kinds of clouds has resulted in their being divided into four principal forms, namely, the stratus, the cumulus, the cirrus, and the nimbus, while from these principal shapes result various modifications.

The *stratus* cloud can be best described as a widely extended but continuous horizontal sheet of vapour, very often forming at sunset.

The *cumulus* cloud is often very like a mountain in appearance, rising from a horizontal base; they are familiar to most people as conical heaps having often a bright or silver lining on the aspect towards the sun. The vapour in cumulus clouds is usually in the form of snow, and at its greatest density.

The *cirrus* cloud is best compared to a series of thin filaments not unlike a brush. It is the loftiest of all kinds of cloud, familiar examples being the so-called mares' tails, or parallel and diverging strips extending in any direction. Cirrus clouds are probably composed of ice or vapour in its least stage of density.

The *nimbus* is the true rain-cloud, being usually a horizontal sheet, having cumulus beneath and laterally, and with rain actually falling from it. Besides these four chief forms, there are compound modifications of them, the names of which are sufficiently descriptive.

Halos and Coronæ are circles which appear round the sun and moon. Halos arise from the existence of minute prisms of ice in the atmosphere, and consist of refracted light; they usually

portend unsettled weather in these latitudes. Coronæ are more common than halos; they arise from the interference of rays of light passing through a mass of minute globules of water, and accordingly are seen whenever light clouds pass between us and the moon.

Atmospheric Pressure.—It has already been explained that the density or pressure which the atmosphere exerts is determined or noted by means of instruments called barometers. These are usually either mercurial, glycerin, water, or aneroid barometers. As commonly constructed, the mercurial barometer consists of a tube of glass about 36 inches long, closed at one end, filled with mercury, and placed vertically with the open end dipping into a cup containing mercury, called the cistern. When discussing the question of the weight of air, the principle of the construction of this instrument was explained, as also was the fact that the difference between the heights of the two mercurial surfaces exactly measured the atmospheric pressure. This in terms of mercury at sea-level, in this country, is 29·92 inches. As the mercury in the tube balances, as it were, the pressure of the air, it is obvious that it falls with a lessened pressure, but rises with an increased pressure, so that if by means of a fixed scale we note the precise length of the mercury column, we may measure the weight of the atmosphere. Such a scale is commonly divided into inches or other measures of length. In some common forms of barometer, this scale is laid off from a zero at some fixed point in the cistern, with the result that, except at one particular point, the instrument reads wrongly, because during the changes which take place in the length of the column, the level of the mercury in the cistern also changes, being sometimes higher and sometimes lower than the fixed zero point. In order to overcome this difficulty and source of error, various expedients have been resorted to, so as to compensate for the ever-changing level of the mercury in the cistern; thus, (1) by a so-called capacity correction which, duly noted and recorded on the scale by the maker, states the ratio of the interior area of the tube to that of the cistern, thus capacity $\frac{1}{40}$. To apply this correction, there is always marked on the scale a certain height of the column which is correctly measured by the scale. This exact height is termed the *neutral point;* when the mercury sinks below this, the height read off will of course be too great, because the level of the mercury in the cistern will have risen above the zero in a proportionate amount; for the same reason, when the mercury rises above the neutral point, the reading will be too small because the level of the mercury in the cistern will have fallen below the zero of the scale. The capacity correction is

applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. Thus, suppose in the case of a barometer marked with a neutral point, and with a capacity correction of $\frac{1}{50}$, the mercury stands 1 inch above the neutral point, then $\frac{1}{50}$ of the difference the height read off and the neutral point, or, in this case, $\frac{1}{50}$, or 0·02 inch, must be added to the observed reading. (2) In the Kew barometers the error is obviated by graduating the scale in nominal inches, which are shorter than true inches, from above downwards in proportion to the relative size of the diameter of the tube and cistern. (3) Another device is to do away with the cistern altogether, and employ a U-shaped tube, in which one arm is shorter than another and open at one end. Both levels are read upon a scale, and the reading of the barometer is the difference in level of the mercury in the two legs. These are sometimes called siphon barometers, of which the ordinary wheel barometer is a common type; in this latter instrument the movements of the mercury are transmitted from a float on the mercury in the open tube, by means of a string, to an axis which carries an index moving over a dial-plate as in a clock. (4) In what are called the Fortin barometers, or best standard barometers, the necessity for capacity correction, or either of the other above-named devices, is avoided by giving the cistern a pliable base of leather, and capable of being raised or lowered by means of a screw *c* (Fig. 75). The upper part of the cistern is made of glass, through which the zero of the scale can be seen as a piece of ivory, whose lower extremity is called the *fiducial point*, *d*. Before taking a reading, the level of the mercury in the cistern must be set exactly to this point, by raising or lowering the cistern base by means of the screw; since the fiducial point is the tip of the piece of ivory, and accurately corresponds, as a fixed point, to the zero of the scale, after the level of the mercury in the cistern has once been carefully adjusted to it, it is obvious that the height of the column of mercury then read will be an accurate measure of the atmospheric pressure.

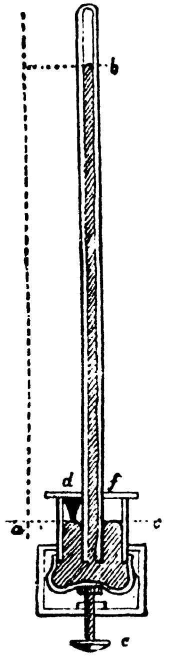

FIG. 75.—Diagram showing cistern of a Fortin's barometer.

In order to secure a greater exactness in the reading of a barometer, use is made of a secondary scale, or vernier, which slides

upon the principal scale. In all standard barometers this vernier scale is so graduated that 25 of its divisions correspond to 24 of those upon the other, or fixed scale. Consequently, each space or division on the scale is $\frac{1}{25}$ of its own size larger than each space on the vernier, and as each such space on the scale is $\frac{1}{20}$, or of $\frac{5}{100}$ an inch, therefore the vernier exhibits differences of $\frac{1}{25}$ of $\frac{1}{20}$ inch, or $\frac{1}{500}$, or 0·002 inch. In taking a reading of a barometer, the first thing to do is to note the temperature of the instrument by means of the usually attached thermometer; next, adjust the mercury in the cistern to the fiducial point, if it be one made on Fortin's principle; then place the vernier so that its lowest edge is level with the top of the mercurial column. If this level coincide exactly with one of the principal scale-divisions, there is no need to use the vernier; but if it do not so coincide, the use of the vernier will accurately measure the excess of the mercury-level over the next lowest division or mark on the scale. To do this, we must follow the vernier scale up, until we find one of its marks exactly corresponds with one on the fixed scale; call it x, and, as each of these represents $\frac{1}{500}$, or 0·002 inch, we have $x \times 0{\cdot}002$ inch as the exact distance which the mercury column is over and above the next lowest mark to it on the principal scale. Thus, in Fig. 76, presuming that the lower edge of the vernier, A B, has been accurately adjusted to the level of the top of the mercurial column, we find that that corresponds to a point just below 29·20 inches, and something above 29·15 inches; that is to say, neither of those readings gives the absolutely correct height of the mercury. Following up the vernier, we find that its seventeenth line or mark is the first to exactly coincide with one on the principal scale CD; therefore, if we read that as meaning $\frac{17}{500}$ of an inch, or 0·034 inch, or the exact amount by which the top of the mercury column exceeds 29·15 on the fixed scale, we get by the addition of these two numbers 29·184 inches, as the correct reading of this particular example.

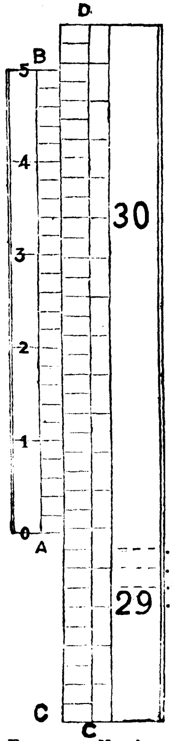

FIG. 76.—Vernier attached to a barometer scale.

The reading having been thus accurately taken, it remains to apply certain corrections; these are (1) index error, (2) for capillarity, (3) for temperature, (4) for height above sea-level.

The first two corrections have to do with the actual instrument, and are usually very small and determined before the instrument is sent out, and their amounts duly entered on the certificate which accompanies the barometer. The error due to temperature is one which affects, not only the mercury, but also the brass of the scale, and in extremes of heat or cold may be considerable; this explains why it is so important to note the temperature before taking the reading. To secure uniformity of barometric records all nations have agreed to reduce their barometer readings to what they would have been had both the mercury and brass scale been at 32° F., or 0° C. All good barometers are made with brass scales, and for these the necessary temperature corrections are given in the following table:—

Temp	27 inches.	28 inches.	29 inches.	30 inches.	31 inches.
30°	−0·004	−0·004	−0·004	−0·004	−0·004
40°	−0·028	−0·029	−0·030	−0·031	−0·032
50°	−0·052	−0·054	−0·056	−0·058	−0·060
60°	−0·076	−0·079	−0·082	−0·085	−0·087
70°	−0·100	−0·104	−0·108	−0·111	−0·115
80°	−0·124	−0·129	−0·133	−0·138	−0·143
90°	−0·148	−0·153	−0·159	−0·164	−0·170
100°	−0·172	−0·178	−0·184	−0·191	−0·197

Corrections for height above sea-level are usually made by reducing all readings to sea-level, which is the level of the mean half-tide at Liverpool. If we know the exact height of the particular spot above or below sea-level, the necessary correction is commonly obtained from specially prepared tables; but the application of this correction is very little needed in everyday life, unless records are made for scientific purposes. As an approximate calculation the correction may be said to be about 1 inch for every 1000 feet.

Although in the majority of barometers the atmospheric pressure is measured by a column of mercury because of its high specific gravity, still, in some others, other liquids are employed, such as glycerin, which, having a lower specific gravity, is much more sensitive to variations in pressure. The specific gravity or density of mercury is 13·59, while that of glycerin is but 1·26; the atmosphere we know can support a mercurial column 29·92 inches high; therefore, it can equally support a glycerin column 27 feet high: or, in other words, a fall of 1 inch in a mercurial column is the equivalent of a fall of 10·7 inches in a glycerin instrument—the latter, in consequence of

its greater range, being far more sensitive as an indicator. Water barometers have also been made, in which the column required to balance the atmosphere is 34 feet. Besides mercurial, glycerin, and water barometers, familiar instruments in general use are aneroid barometers—their principle is very simple. They are small, air-tight metallic boxes, exhausted of air inside, and so constructed that as the atmospheric pressure rises so the metal box is forced in, and, helped by means of a strong spring, bulges out again when the pressure lessens. The movements of the metal are, by a suitable arrangement of levers, made to turn an index on a dial face. The dial is of course graduated by comparison with a standard mercurial instrument. Aneroids are very sensitive and convenient, but liable at times to go hopelessly wrong, on which account they need to be periodically checked against a standard mercurial instrument. Mercurial barometers may be said to measure *absolute* pressure, while aneroids measure *relative* pressure.

By a combination of a series of aneroid vacuum boxes, the movements of which by means of a lever are multiplied, and recorded upon a revolving cylinder, so-called recording barometers have been made, and for observatory work these instruments serve a useful purpose, but, of course, are not absolutely accurate without being constantly checked against standard mercurial instruments.

Barometers generally, and aneroids in particular, have been of the greatest value as measurers of the height of any given place above the sea-level; the barometer, of course, falls when heights are ascended, but the diminution of pressure is not uniform. Strictly speaking, such observations involve calculations of more or less complexity, but, for rough work, fairly accurate results can be obtained by simple rules. It is, however, necessary to make three readings of the barometer. Suppose it is required to know how much higher a town, A, is above a source of good water-supply situated at B. Read the barometer at A, go then to B and read it there, then back to A and read it there again; take a mean of the two readings at A, and determine the difference between it and the reading at B; this, multiplied by 9, and neglecting decimals, will give the difference in height between the two places in feet. Thus, suppose the first reading at A had been 29·94, and the second had been 29·90, the mean, of course, would be 29·92; and suppose the reading at B to have been 30·35, the difference between these two is 0·43, which, multiplied by 9 and ignoring decimals, gives 387 feet as the height of A above B. When the barometer at the higher station is below 26 inches, or the temperature above 70° F., the multiplying factor

same temperature, 1·1021 cubic feet, with a weight of 550·9 grs.; so that 1 cubic foot of the saturated air weighs but 544·3, or 2·3 grs. lighter than it did when dry. It is this physical fact of moist air weighing lighter than dry air that causes the barometer to fall in consequence of lessened atmospheric weight when much moisture is present, and, consequently, rain imminent. It must, however, be remembered that other causes than moisture will often affect the barometer, notably wind, though, in the main, its movements are dependent largely upon the presence or absence of watery vapour in the air. It was the early recognition of this fact that led to the use of the barometer as a weather-indicator. In former years the value of the barometric reading was necessarily limited to the particular spot at which it was noted; but recently, as the result of increased facilities of communication between one place and another, it is possible to obtain simultaneous readings of the barometer at any given time at several spots distributed over a wide area. Now, if these are recorded on a map, and lines be drawn between and connecting all places where the same pressure prevails, we obtain what is called a *synoptic chart*, made up of lines of equal barometric reading, or *isobars*, as they are termed. This is what is actually done in all the chief meteorological stations, and experience has shown that these isobars commonly assume certain typical forms or shapes, which are again usually associated with certain kinds of weather. It is upon these data and facts that the modern methods of weather forecasting are based.

Isobars, or lines drawn on a chart indicating places of equal barometric pressure, are found to arrange themselves practically

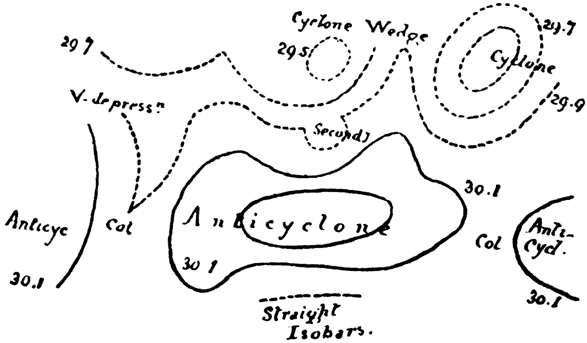

FIG. 77.—Diagram showing the chief types of isobars.

into seven different shapes called cyclones, secondary cyclones, V-shaped depressions, anti-cyclones, wedges of high pressure,

cols and straight isobars; the general characteristics of each are shown in Fig. 77. The closeness of the isobars one to another, or the rapidity of changes in pressure, constitute what is called the "barometric gradient," and just as we measure and express a railway gradient as being 1 in 20, 1 in 100, and so on, so can we say that barometric gradients are so many thousandths of an inch in 15 miles, or so many millimetres in one degree of the meridian. The steepness of the barometric gradients directly governs the velocity of the wind over any particular place, the wind's velocity being greatest at the localities of steepest gradient, and *vice versâ*. In addition to this, if the wind's direction at each place be noted on a synoptic chart, it is found to be nearly parallel to the trend of the isobars, and tends to cross from the higher to the lower ones. This fact has found expression in what is known as Buys Ballot's law, namely, that if you stand with your back to the wind, the lowest pressure lies to your left and in front.

Cyclones.—An area of low pressure, and the whole system connected with it, is called a depression or cyclone, and in America "a low." As seen on a synoptic chart, cyclones are circles formed by concentric isobars, in which the outer lines mark a higher pressure than the inner ones; they constitute the most frequent arrangement of isobars in these latitudes (Fig. 78). They usually travel from west to east, at the rate of about 20 miles an hour, and are invariably associated with bad weather. From what has already been said, it is evident that the actual pressure or height of the barometer is of little moment; the forces involved are due to the gradients or differences of pressure, and are greater the steeper the gradients. Hence a cyclone may be of a mild type, or be a gale or hurricane, according as to whether the gradients are gentle or steep. If we analyze the weather associated with a cyclonic disturbance, we find that the foremost portion of a cyclone area is always marked by stratiform clouds, moist heavy atmosphere, and the usual signs of coming rain, such as a pale moon, watery sun, dirty gloomy sky. As the cyclone advances, a drizzling gradually changes into a driving rain, accompanied in the trough or situation of lowest pressure by squalls of wind. As the cyclone area shifts its position or moves onward, the rain moderates into showers, followed by a brighter sky with cumulus clouds and a sharp brisk feeling in the air. If we study the barometer changes at different points in the path of a cyclone, it is at once obvious that in the fore part of the area of depression the barometer is everywhere falling, while in the rear part it is everywhere rising, and the turning-point, or line of lowest pressure, is what is called the trough. A cyclone may be compared to a cup-shaped hollow, the isobars being simply

contour lines. The extent or area of a cyclonic disturbance may vary from 10 or 20 to some thousands of miles, covering even the whole Atlantic or the greater part of Europe. Cyclones are usually oval and not circular in form, their longest diameter being in these latitudes in a direction nearly W.S.W. to E.N.E. in the majority of cases. When the dimensions become great, especially if the system be much elongated, a cyclone frequently breaks up into two, three, or even more separate centres of depression. Large cyclones are, of course, much modified in both form and position by the variations of the deflecting force due to the rotation of the earth, and arising from difference of latitude. As a rule, the higher the latitude, the greater is the average size of cyclones. In the tropics, cyclones are usually smaller and circular. It is important, however, not to confound small cyclones with either waterspouts or tornadoes, which are too small to be much influenced by the rotation of the earth,

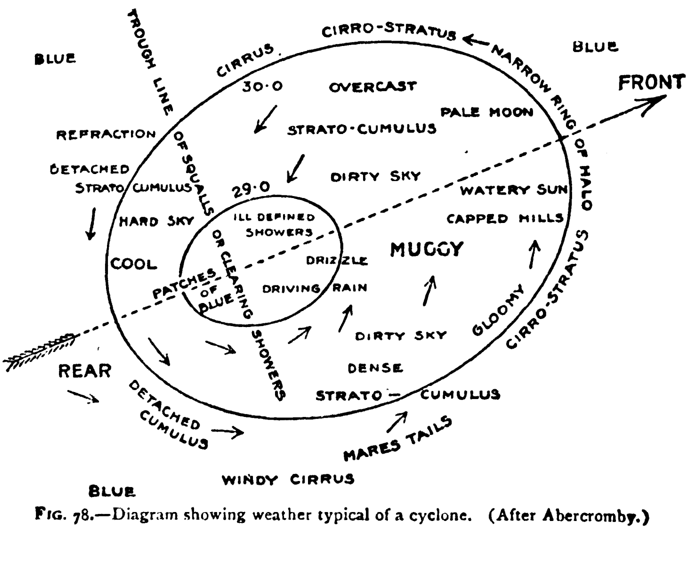

FIG. 78.—Diagram showing weather typical of a cyclone. (After Abercromby.)

besides which they are special phenomena of a distinct nature. The direction of the wind is, in all cyclones, obliquely across the isobars, and may be described as blowing spirally into the area of low pressure towards the centre, and from the central area in an upward direction. The particular angle at which the incurving of the wind takes place in a cyclone depends on the friction

between the air-currents and the earth's surface, the angle being smaller the greater the friction. Thus, according to Ley, the angle between the direction of the wind and the isobars is 29° for coast stations, and 13° for inland stations, thus showing distinctly the increased effects of friction on land. It has already been stated that cyclones in these latitudes for the most part move in an easterly direction; when a westward motion occurs, it is usually slow and seldom long-continued. The advance of a depression is commonly in a direction perpendicular to the line of steepest gradient, so that the highest pressure lies to the right; while also the temperature is highest to the right of its track. The rate of advance of a cyclone varies within very wide limits; on the whole, deep depressions move faster than shallow. The average rate of motion of translation of cyclones over Europe is from 20 to 30 miles an hour, while in America they travel commonly as rapidly as 50 miles an hour. So far as is known, cyclonic storms and weather seldom or never originate within five degrees of the equator, but this intermediate tropical belt is the scene of extremely violent hurricanes, which have a tendency to move in a westerly or north-westerly direction, and, moreover, appear to behave according to laws too complex to be given in detail here. The general weather characteristics of a northern cyclone area are given in Fig. 78, which shows such an arrangement of isobars shifting in a north-easterly direction.

Secondary Cyclones are areas of low pressure formed by looped or incompletely circular concentric isobars with the lowest pressure in the centre. They have many weather features in common with primary cyclones, moving like them mostly from west to east. They frequently follow primary cyclones, and their bad weather is usually associated with calm and stationary barometers.

V-shaped Depressions are angular intervals or areas with the lowest pressure in the interior, and frequently form between adjoining anticyclones, and are, as it were, a specialized form of cyclone, or even may form part of a cyclone. They have been aptly described as tongues of depression projecting from a cyclone situated to one side; in the northern hemisphere the point or tip is usually towards the south. These V's commonly move from east to west, and the weather experienced by an observer over whom one of these areas of depression drifts is from blue sky to cloud, later on rain with a falling barometer and south-west wind, then a squall, during which the wind jumps round to north-west, followed by a rapidly clearing sky and a rising barometer. This type of isobars is always associated with squalls or thunderstorms. Not only secondary cyclones but V-shaped depressions are in general most uncertain in their movements, and their occurrence

is consequently very difficult to foretell. The extreme rapidity with which they travel at times, and the violence of the wind and rain developed within them, render them a source of great danger to both life and property. The peculiar summer thunderstorms of Central Europe and America are nearly always associated with V-shaped depressions.

Anticyclones.—These are areas of high pressure formed by more or less circular isobars, with the highest pressure in the centre. They differ from all other arrangements of isobars in tending to remain stationary and, too, to extend over large areas. The air is calm and cold in the centre, while on the borders the wind blows round the centre spirally outwards in the direction of the hands of the clock; thus, on the east side the wind comes

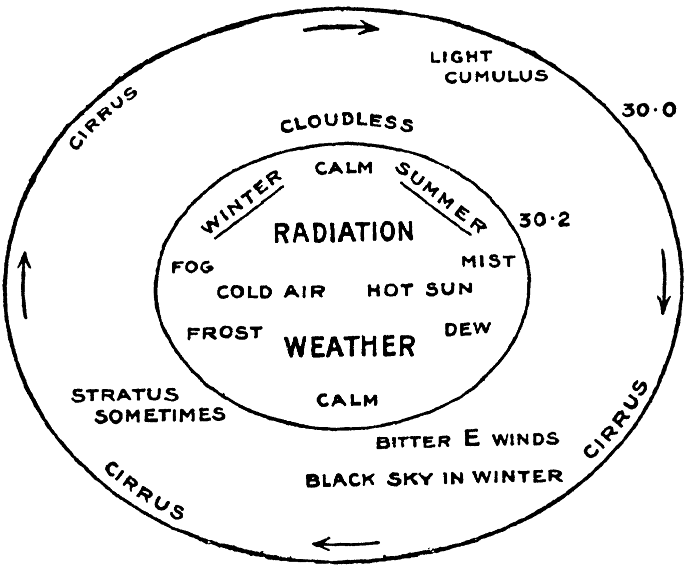

FIG. 79.—Diagram showing weather typical of an anticyclone. (After Abercromby.)

from the north, on the south from the north-east, on the west from the south-east, and on the north from the west. In describing the cyclonic system it was explained how the wind in the centre of that system was an ascending current; that wind circulation is compensated by an equivalent descending current in what is in all respects the opposite of the cyclone, namely, the anticyclone. The characteristic circulation of the air in this is

therefore exactly the reverse of that in a cyclone: it blows in the same direction as the hands of the clock, more spirally outwards from the centre at or near the surface of the earth, and inwards towards the centre at the level of the highest clouds. In anticyclonic systems the barometric gradients are slight, and the normal wind circulation usually disturbed or disguised by accidental or local causes. The general weather features of an anticyclone are given in Fig. 79, from which it will be seen that they are the exact opposite of cyclonic conditions, being blue sky, dry cold air, a hot sun, little or no wind, and a hazy horizon—in fact, fine weather. The diagram shows in one half the summer characteristics of an anticyclone, in the other those of winter. Certain regions of the globe are remarkable for the existence of permanent and recurrent anticyclone systems. There is a permanent area of high pressure near latitude 30° north, called the Atlantic Anticyclone, which varies in extent from month to month, attaining its greatest intensity in summer and least in winter. Another permanent area is that over the large land surface of Asia and Eastern Europe in which the pressure is usually excessive during winter. It is the existence and more or less permanency of these two large areas of high pressure which combine to give a north-westerly gradient towards a stationary low-pressure centre near Iceland and to govern the motions of cyclones, which tend to skirt round their borders in an easterly direction. It is important to remember that, while an anticyclone system compensates a cyclone in the matter of transferring air from one level to another, there is no mutual relation between them in the sense of cause and effect.

Wedge-shaped Isobars usually point to the north and indicate areas of high pressure moving along between two adjacent cyclones. Though very usually associated with fine weather, it is only temporary because wedges of high pressure are never stationary, and are commonly followed by well-defined cyclonic areas. So far as weather is concerned, we may regard the two sides of the wedge as the rear and front of cyclones, and the wedge itself as a mere projecting tongue of an anticyclone. The wide end of the wedge is often associated with fog, and the narrow end with thunderstorms or showers.

Cols, or necks of comparatively low pressure, generally lie between two anticyclonic areas. Over them the weather is dull, gloomy, and stagnant, while in summer violent thunderstorms are frequently associated with them. Like the following, cols are essentially intermediate systems.

Straight Isobars are those without any curve, and may trend in any direction. This arrangement of isobars only marks the

position of a barometric slope, and does not include any area of either high or low pressure. This form is essentially temporary and an intermediate arrangement of the atmospheric circulation or pressure which precedes the formation of a cyclone. The weather associated with straight isobars is too transitional to be characteristic, but very frequently is that of a hard sky, with a blustering wind and an inclination to rain, such as one experiences as to remark that "when the wind falls it will rain."

What are known as squalls, or puffs of wind of varying intensity, appear to be caused by the sudden breaking of the cold dense upper layers of air through lower and warmer layers lying underneath, condensing the vapour in the latter and causing them to ascend. In contrast to them are the various kinds of squall attributable to the sudden ascent of masses of warm air; examples of this phenomenon we know, as the familiar dust whirls on a dry road, or the dust storms, waterspouts, and tornadoes of the tropics. Their causation is unknown.

It must not be forgotten that all the foregoing forms of isobars are at any time liable to break up, or at least pass into new forms, so that, although every part of every shape of isobars has a characteristic weather and sky appearance, still, owing to their often rapid breaking up, forecasting of weather is not always certain to come true. Cyclonic disturbances, for instance, are frequently diverted from their course by meeting a coast line or range of mountains, or even by the formation of areas of high pressure; so that their velocity is neither regular nor their direction of movement necessarily straight. On the other hand, experience shows that when advantage is taken of Transatlantic and other meteorological observations telegraphed to a central meteorological office, synoptic charts can be prepared of such magnitude and detail as to render weather forecasting comparatively successful in a great percentage of cases. All meteorological phenomena are practically the products or results of the circulation or motion of a moist atmosphere, and consequently forecasting weather is nothing more than saying how and where certain air-currents or eddies will move, or when new ones will form, and whether they will be gentle or violent. From the rapidity with which meteorological changes take place, the use of telegraphy is absolutely necessary if any success is to be attained in forecasting, and even this information can be only of use in some central office presided over by an experienced forecaster thoroughly conversant with the motions of low-pressure areas in his own country. It will be readily understood that in some countries forecasting is easier than in others. Thus,

in the temperate zone, where most disturbances move from the west, those countries will be best suited for weather forecasting which lie to the east of a well-observed land area. For this reason Norway and Germany are better placed for weather forecasting than either France or England. Large areas of land and water mainly determine the great areas of high and low pressure, hence Great Britain being placed where it is, on the boundary, so to speak, between anticyclonic and cyclonic systems, renders the prognostication of weather peculiarly difficult in these islands, more particularly as their geographical position precludes an early knowledge of cyclones forming over the Atlantic. Moreover, just as an outlying rock is exposed to the wash of every sea, so is England exposed to the disturbing influences of every type of European or Atlantic weather, and has, in consequence, more unsettled weather than any other part of Europe.

CHAPTER XI.

VITAL STATISTICS.

PROBABLY no single cause has contributed more to the attention now paid to questions of public health than the careful collection of the statistics of births and deaths, and of the causes of death which have been collected and published by the Registrar-General's Office in England during the past fifty years. These collections of figures and facts are usually spoken of as vital or health statistics, because they are so intimately associated with the various problems relating to the health and chances of life which the community enjoys. So valuable has been the work done, that we are now able to determine with some precision the causes and limits of mortality, and by the study and analysis of the collection of facts known as vital statistics to apply them as tests of the health of the communities to which they refer.

The chief vital statistics, bearing upon public health, relate in detail to past and present facts concerning populations, age and sex distribution, births, marriages, deaths, diseases, duration of

the hours of occupation and general social conditions, such as the health of each class of the community as judged of by the expectation of life at given ages. Statistics of sickness, apart from mortality, have as yet not been attempted, chiefly on account of the difficulty in collecting the data with accuracy.

Population.—The very first necessity is to know what is the precise number of the people. Our knowledge upon this point in each place in Great Britain depends primarily upon the census returns which have been made regularly and with increasing care every ten years since 1801. It will be at once obvious that the facts relating to the numbers living of each sex and age periods and the numbers employed in certain callings can only be accurately known in actual census years, and making from them estimates for intermediate years. An interval of ten years between the takings of the census is now acknowledged to be too long, and it is probable that if our population statistics are to remain in any way accurate, more frequent enumerations of the people will need to be taken, and even then certain inaccuracies are sure to exist, due chiefly to the imperfect education of large numbers of householders and heads of families, these defects of information collected relating especially to occupations and ages. It is remarkable what a large number of people do not know their precise age, these persons generally giving their age in census returns in some multiple of ten. Another source of error and perplexity in all census returns is the too frequent wilful misstatements made by women, owing to their desire, for various reasons, to be thought between 20 and 25 years of age. This is shown by the fact that in each successive census, the number of women returning themselves as between 20 and 25 is larger than the number of girls returned in the census of ten years before as between 10 and 15 years of age. The former being only the survivors, after the lapse of ten years of these latter, they should of necessity be fewer in number. The male sex is not altogether free from blame in the same matter, though the bias goes in the opposite direction. Thus, men of the poorer classes, who have passed the age of 60, constantly overstate their age for the sake of certain definite advantages, such as getting old-age pensions, outdoor relief, or, if entering the poor-house, gaining some special privilege not granted to their juniors. Some really old people often exaggerate their age in order to appear as centenarians.

In attempting to estimate the population of any given locality for any year intermediate between the collection of census returns, it is necessary to calculate the probable decrease or increase of the particular population by comparing the numbers of the latest

enumerations. Thus, say a town had in 1901 a population of 35,626, and in 1911 one of 38,754, and it was required to know its estimated population in June, 1918: it is only fair in such a case to assume that the 1918 population will be greater than the 1911, and, if we further assume that the increase will be at the same rate as between 1901 and 1911, by taking the difference between the 1901 and the 1911 populations and dividing by ten, we get the annual increase of population for that town. Inasmuch as the census is always taken in the first quarter of the year, and we require the population at the end of June, 1918, an interval of $7\frac{1}{4}$ years will have elapsed since the last census; if, therefore, we multiply the annual increase of population, which in this example is $\frac{38754 - 35626}{10} = 312{\cdot}8$, by $7{\cdot}25$, we get an increase of 2267 to be added to the 1911 population, giving an estimated population of $38{,}754 + 2267$, or 41,021 for the middle of 1918.

The foregoing method of calculating an estimated population is fallacious, as it presumes the increase or decrease will be as in an arithmetical progression. The true law of population increase or its decrease is that of a geometrical progression, and is very suitably compared to the increase of a sum of money at compound interest. The increase in x years is derived from the increase in one year by multiplying 1 *plus* the annual rate of increase x times into itself. If the increase in one year be 1·5 per cent., 1 becomes 1·015 in one year, and 1·015 multiplied x times into itself will give the increase in x years. To obtain, therefore, the annual rate of increase in x years, the *xth root*, and not the *xth part* of the x rate of increase, must be taken. It is on this assumption, that the increase or decrease of a population proceeds as in a geometrical and not in an arithmetical progression, that the Registrar-General calculates the estimated populations for London and other large towns, as well as for the whole country, for intercensal years. On this basis the calculations are more conveniently performed by logarithms in the following manner:—

Taking the same example as above, we find the logarithm for the 1911 population, or log 38,754 = 4·5883165, and deduct from it the logarithm for the 1901 population, or log 35,626 = 4·5517671; this gives 0·0365494, which is the logarithm of the decennial increase. Dividing this by 10 gives us 0·0036545, or the logarithm of the annual increase, and a quarter of this is 0·0009136, or the logarithm of the quarterly increase. By adding together the logarithm of the 1911 population and seven times the logarithm of the annual increase and the logarithm of the quarterly increase, we get the logarithm of the mid-year 1918 population, or 4·6148116, which, by reference to a set of tables, = a population

of 41,260, or somewhat higher than the estimation made by that of a simple arithmetical progression.

Unfortunately, these assumptions as to a uniform increase or decrease of numbers are largely arbitrary or conjectural, and but rarely agree with the actual facts as found by the next census. Thus the population of Cardiff as estimated in 1901 by the Registrar-General was 200,808, but when actually enumerated by that year's census was found to be 164,420 only; that is, the rate of increase of population during the ten years 1891–1900 had been much less than in the preceding decennial period. In a similar way the total population of England and Wales at the census of 1901 was found to be 32,526,075, showing a rate of increase during the ten years 1891–1900 of 12·17 per cent. as against 11·65 between the 1881–90. In 1911 the population was found to be 36,070,492, showing that in the last decennium the rate of increase had dropped to 10·9 per cent.

The same thing was found to have occurred in regard to the populations of most of the large towns, with the result that their calculated death-rates had been returned too low. These erroneous estimates of population have obvious vitiating effects on vital statistics. The only remedy is a more frequent enumeration, as offered by a quinquennial census.

As the Registrar-General has pointed out, the official method of calculating populations by the assumption of an equable rate of growth is only trustworthy in the case of very large communities, where any abnormal increase in one direction is sure to be counterbalanced by an abnormal decrease in another. It is hardly suited for very small communities, where growth is very often most irregular and spasmodic.

A moment's reflection will show that many circumstances may help to quicken or slow the increase of a population. The increase in any given population may be either *natural* or *actual*. The former is merely the excess of births over deaths, while the latter is dependent upon the balance between births and immigration on the one hand, and deaths and emigration on the other. The facts revealed by the last census, in 1911, showed a decline in the natural increase of population for England and Wales; this was not due to any increased mortality, but rather to a decline in the birth-rate. For the whole country the actual increase, as shown by the last census, also showed a decline, due mainly to an excess of emigration over immigration during the last decennium. As a general rule, in towns the *actual* increase is greater than the *natural*, simply because there is a natural tendency for people to migrate from rural to urban districts; and with regard to such local migrations, at present we have no available or

systematic record. It is well known that in times when trade is bad in certain localities, a considerable movement of the population occurs to other parts, and *vice versâ*.

Although not officially recognized by the Registrar-General, there are several methods of checking estimated populations, which, if used judiciously, are of great value. Amongst such are examinations of inhabited houses as ascertained from the rate-books, and then, assuming the density to remain the same, to multiply the number of inhabited houses by the average number of persons per house. Care, however, must be taken to allow for any marked change in the class of new houses built, whether containing fewer or more occupants than others, and, too, to allow for block buildings, flats and large hotels, all of which are liable to seriously affect statistical results.

Age and Sex Distribution.—This is sometimes spoken of as the constitution of a population, inasmuch as it shows the proportion in which males and females, and persons of different ages or of different callings, enter into the composition of the community. These figures and facts are of course only obtained at each census, and generally may be taken to remain constant till the next census. The effect which these facts have upon mortality statistics will be explained later on; at present, allusion need only be made to the very marked difference which exists in the age distribution between the populations of town or urban and those of rural districts. The 1911 census gives for England and Wales the following age and sex distribution of the population in town and country:—

	Urban districts.			Rural districts.		
	Persons.	Males.	Females.	Persons.	Males.	Females.
All ages .	28,162,936	13,628,189	14,534,747	7,907,556	3,957,483	3,950,073
0 to 5 .	3,022,864	1,505,267	1,517,597	831,519	416,601	414,918
5 ,, 10 .	5,571,632	2,776,720	2,794,912	1,624,852	814,861	809,991
10 ,, 15 .	2,614,322	1,295,793	1,318,529	722,299	398,263	324,036
15 ,, 20 .	2,537,275	1,179,035	1,358,240	638,413	338,075	300,368
20 ,, 25 .	2,469,831	1,198,205	1,271,626	60[illegible],229	290,245	318,984
25 ,, 35 .	4,383,189	2,106,798	2,276,391	1,107,256	542,119	565,137
35 ,, 45 .	3,256,067	1,578,868	1,677,199	902,133	445,766	456,367
45 ,, 55 .	2,206,390	1,052,031	1,154,359	674,721	331,486	343,235
55 ,, 65 .	1,352,459	616,978	735,481	474,309	229,082	245,227
65 ,, 75 .	610,218	263,821	346,397	253,264	120,074	133,190
Over 75 .	138,689	54,673	84,016	69,531	30,911	38,620

The table shows that, as compared with the country districts,

in the towns of England and Wales there is a great excess of persons from 15 to 45 years of age, and a small proportion of children between 5 and 10 years of age. The probable explanation of these figures is the persistent immigration of young adults from the country to the urban areas in the one case, and the higher infantile mortality of the towns than of rural districts in the other. The proportion of females to males, of all ages, is much higher in towns than in the country, being 108 to 100 in the former, but only as 101 to 100 in the latter. These proportions are only manifest after the 10 to 15 age period, when the girls begin to migrate into the towns as domestic servants. The migration of girls into towns is soon followed by that of boys, with the result that the unequal proportion of the two sexes in towns in the 15 to 20 age period is considerably reduced, and continues to be so during all the more active working ages, or the period from the end of the 25th to the end of the 45th year of life. In the later years of life, the disproportion between the sexes in the towns again increases, so much so that in the 55 to 65 years period the women are 20 per cent. more numerous in towns than the men, but only about 5 per cent. more numerous in the country. In the 65 to 75 period the excess is 33 per cent. in the towns, and only 7 per cent. in the country; while in the over 75 years period the excess of women becomes 55 per cent. in the towns, and only 15 per cent. in the rural districts.

As the Registrar-General has pointed out, this increasing excess of females in the late-age periods, so far as it is common to both towns and country, is, of course, due to the fact that women are longer lived than men—that is, they survive when the men die off. The greater excess of women over men in towns than in the country is less easy of explanation. It may be due to the fact that men, as they get old, leave the towns where the struggle for existence is so much the more keen, and retire into the country more rapidly than do the women; or it may be due to differences between the conditions of town and country life being more hostile to old men than to old women. Possibly both causes are at work. We know that for some reason or other urban life is exceptionally fatal to elderly men, and that towns offer, even to those in advanced age, more chances of comparatively easy work to women than to men; hence there is more inducement for women than for men to remain in the towns when they have grown old, especially as town life is much less healthy for men than for women. The practical importance of this question of age and sex distribution in vital statistics will be apparent when we come to consider the value of death-rates.

Birth and Marriage Rates.—The Births and Deaths Registration Act of 1874 compels every birth to be registered within 42

days of its occurrence. The number of births per 1000 persons living, or birth-rate, as it is so called, averaged 28·7 per 1000 in England and Wales, during the decennium 1896–1905, the highest rate of 36·3 ever recorded in this country having been reached in 1876 and the lowest or 17·7 in 1918. This latter rate indicates a fall of over 25 per cent. since 1914. If we assume that under peace conditions the decline would have continued at the average pre-war rate, then 4·9 of the total decline of 6·1 since 1914 must be attributed to the war. The birth-rate varies in different towns or localities, being higher in towns and during times of commercial prosperity, and of course lower in rural districts and during periods of trade depression. Bad trade and bad harvests also diminish the number of marriages, and consequently lower the number of children born.

The birth and marriage rates are readily found by a simple proportion sum; thus, if the population of a town be 13,621, and the number of births and marriages during the year are respectively 441 and 215, then $\frac{441}{13621} \times 1000 = 32·3$ birth-rate per 1000, and $\frac{215}{13621} \times 1000 = 15·7$ marriage-rate per 1000. This method of stating the ratio of births, marriages, or deaths in one year, as per thousand persons living in a place, is the most usual and convenient, but occasionally it may be necessary to compare these rates for shorter periods, say weeks, months, or quarters; in which case it is done in the following way. Suppose it is required to know the birth-rate during $\frac{1}{n}$ part of a year, then—

$$\frac{\text{Number of births during the period in question}}{\text{Population in the middle of the year}} \times n \times 1000 =$$

birth-rate of period in question. Taking the preceding example, and required the birth-rate during one week, or $\frac{1}{52·17747}$ part of a year, during which period 10 births have taken place, we get $\frac{10}{13621} \times 52·17747 \times 1000 = 38·19$ or birth-rate.

When comparing one community with another, to be strictly fair, the birth-rate should be calculated on the total population only after it has been reduced to a common or normal constitution as regards sex, age, and marriage. This is the best secured by calculating the birth-rate on the number of women between 20 and 40 years of age who constitute the great majority of child-bearing mothers. More males appear to be born than females, in the proportion of 104 to 100. The number of illegitimate children born is increasing, having increased by 11·6 per cent. in 1918, while legitimate births have decreased by 1·6 per cent. This illegitimate birth-rate varies much in different districts; thus the registration counties in which the proportion of illegitimate to

total births was highest, were Nottinghamshire, Norfolk, Suffolk, Shropshire, Staffordshire, and Radnorshire.

Closely connected with the birth-rate is that of the marriage-rate, and both are intimately involved in the question of population increase. In this country, the number of married persons per 1000 of living has averaged during the last 50 years something like 16 or 17; but of late years it has steadily fallen. In 1918, 15·3 persons per 1000 living married. Like the births, the marriages usually closely follow the fluctuations in commercial prosperity, but it is affected also by the proportion of marriageable persons in the population. The rates for 1918 were 51·9 for males and 41·0 for females. The mean age at marriage is 30 for males and 27 for females. The most disquieting feature of our birth and marriage statistics is the steadily falling birth-rate and the reduced number of children to each marriage. This is to be deplored, and, if continued, amounts to gradual depopulation and the gradual reduction of England and the British Empire to the level of a second-rate Power. It is as much a mistake to suppose that the inhabitants of a country are in proportion to their food, as it is to think that the productions of a country are in proportion to the number of its inhabitants. The truth is, the population that a country sustains does not depend exclusively on the amount of subsistence existing in it at any one time, but rather that the produce of a country is limited chiefly by the character of its inhabitants, and the more civilized and cultured they are, the greater will be the products of their industry. Unfortunately, population is often out of the place where it is wanted or could be most productive; but at no time can it be said that the population of these islands is excessive.

Death-rates.—By the Births and Deaths Registration Act of 1874, all deaths must be registered within five days of their occurrence. In 1918, the deaths registered in England and Wales were in a proportion of 17·1 to every 1000 persons living. The death-rate is obtained in exactly the same way as that for births —by multiplying the actual number of deaths from all causes by 1000, and dividing the product by the population; this is known as the general or gross death-rate. In a similar way as explained above for calculating the weekly or quarterly birth-rate, so is the annual death-rate for the week, month, or quarter obtained.

Thus, take a town with a population of 20,000 and the deaths in any week being 8, the annual death-rate for that week will be 21, or $\frac{8}{20000} \times 52{\cdot}17747 \times 1000 = 20{\cdot}87$. These so-called weekly death-rates are convenient for reports, but are not reliable data on which to compare the relative conditions of places, as much of the mortality often depends upon epidemics, weather, and other causes of a temporary nature. These death rates, as

published for each week by the Registrar-General, must therefore not be regarded as actual rates, but rather as annual rates per 1000, representing the number who would die supposing the same proportion of deaths to population held good all through the year. Their chief value is for contrasting mortality rates of any given place at corresponding periods of some previous year. The value of the general death-rate has been much criticized on the ground that it is much influenced by movements of the populations, by the presence of large institutions, such as hospitals, by the age and sex distribution of the population, and by the birth-rate. All this is quite true, but still, if due correction be made, it is probably, in the case of large populations, the most trustworthy test we have of relative vitality. The corrections most advantageously applied to general death-rates are: (1) for non-resident, or migratory people; (2) for age and sex distribution.

The correction for a migratory population is most difficult to apply, as it is not easy to trace and control the facts relating to visitors and immigrants. In the case of watering-places and favourite residential towns, corrections in this direction are most important, and are largely made by the officials from materials obtainable from the sub-registrars; but, even under the best supervision, considerable disturbance and fallacies to the statistics occur. Closely allied to the consideration of migration is the effect which public institutions, such as poor-houses or hospitals, exert on local death-rates, as the disturbance arising from them is due to migration into them from neighbouring districts. To meet this difficulty, the rule is to deduct the deaths of those inmates drawn from outside areas, at the same time adding the deaths of proper inhabitants of the place which may have occurred in other institutions outside the district. Each sanitary authority in London and in every urban and rural district in England is supplied quarterly by the Registrar-General with particulars of death of their inhabitants, so that the deaths in all these cases may be apportioned to their proper districts. All general death-rates require to be corrected for age and sex distribution. Females live longer than males. It follows, therefore, that if two towns were in an equally healthy state, but that one of them contained a larger proportion of females than the other, the one with the lower proportion of females would have the higher death-rate. Similarly, there is a great tendency to death among infants; this liability to die reaching its minimum from between ten to fifteen years of age, and afterwards steadily increasing throughout life.

The following table shows the mortality from all causes in England and Wales during 1918 expressed per million. The term "standardized death-rate" means the death-rate corrected for differences of sex and age constitution of the population.

—	Males. 1918 (Civilians only).	Females. 1918.	Persons. 1918 (Civilians only).
All ages, Crude	21,098	15,086	17,560
All ages, Standardized	19,814	14,642	17,095
0–	38,523	33,847	36,201
5–	5,271	5,554	5,412
10–	3,413	3,880	3,647
15–	?	5,964	?
20–	?	7,691	?
25–	?	9,291	?
35–	?	8,646	?
15–45	*14,663*	*8,201*	*10,176*
45–	16,754	12,904	14,731
55–	29,554	22,893	26,127
65–	64,652	49,625	56,363
75–	139,540	112,628	123,319
85 and upwards	246,705	242,691	244,122

It follows, therefore, that a town, a large proportion of whose inhabitants were at the most viable age, would have a lower death-rate than a town equally healthy, in which the ages of the people were less favourable to long life; just as it would be if the one town had a much larger population of females than the other. In order to neutralize these errors, the Registrar-General has devised a method by which they can be corrected.

This method, based primarily upon the death-rate of each sex at different ages throughout England and Wales, provides a series of factors by which the recorded death-rates of the great towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors, the recorded gross death-rate of any of these towns can be lowered or raised to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. This new rate is called the *corrected death-rate.* The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical (arbitrary) *standard death-rate*, calculated on the hypothesis that deaths at each age period were at the same rate as in England and Wales during the decennium 1896–1905, the death-rate at all ages in England and Wales during that period having been 18·194 per 1000. Owing to the proportions of persons of low mortality being excessive in most towns, their recorded death-rates are too low, and in consequence the factor for their correction is in most cases above unity, the only exceptions being Hastings, Southampton, Ipswich,

Brighton, Yarmouth, Norwich, and Plymouth. The table below gives these factors for the chief towns as issued by the Registrar General in 1912, along with their recorded or crude death-rates per 1000 living in 1911:—

Towns, in the order of their corrected Death-rates, 1911.	Factor for Correction for Sex and Age Distribution.*	Crude Death-rate.		Corrected Death-rate.		Comparative Mortality Figure, 1911.†
		Average 1906–10.	1911.	Average 1906–10	1911.	
Cols.	1.	2.	3.	4.	5.	6.
England and Wales .	1·0000	14·70	14·60	14·70	14·60	1,000
England and Wales, less the 77 Great Towns	9·9637	14·02	13·89	13·51	13·39	917
77 Towns . .	1·0627	15·54	15·48	16·51	16·45	1,127
King's Norton . .	1·0456	10·16	9·09	10·62	9·50	651
Hornsey	1·1400	9·56	9·51	10·90	10·84	742
Handsworth . . .	1·1007	10·66	10·29	11·73	11·33	776
Bournemouth . . .	1·0566	12·20	11·41	12·89	12·06	826
Croydon	1·0250	12·12	11·83	12·42	12·13	831
Ipswich	0·9766	14·58	12·46	14·24	12·17	834
Reading	1·0343	12·80	11·84	13·24	12·25	839
Walthamstow . . .	1·0572	12·18	11·61	12·88	12·27	840
Leyton	1·0285	11·38	12·09	11·70	12·43	851
Willesden	1·0728	11·50	11·76	12·34	12·62	864
East Ham	1·0671	12·04	12·13	12·85	12·94	886
Hastings	0·9616	13·68	13·59	13·15	13·07	895
Great Yarmouth . .	0·9152	15·44	14·30	14·13	13·09	897
Coventry	1·0024	12·62	13·12	12·65	13·15	901
Norwich	0·9541	14·96	14·15	14·27	13·50	925
Wallasey	1·0940	12·66	12·34	13·85	13·50	925
Brighton	0·9856	14·84	13·75	14·63	13·55	928
Northampton . .	1·0397	12·94	13·18	13·45	13·70	938
York	1·0297	13·68	13·39	14·09	13·79	945
Devonport	1·0486	13·04	13·38	13·67	14·03	961
Tottenham . . .	1·0791	12·42	13·10	13·40	14·14	968

* The Factor for Correction is the figure by which the Crude Death-rate should be multiplied in order to correct for differences of age and sex constitution of population. For method of constructing these factors see Annual Summary, 1908, pp. x.–xiii. These Factors being necessarily based upon the constitution of the population as enumerated in 1901, are only approximately applicable to the conditions of 1911 owing to the changes which must have occurred meanwhile in the constitution of the various populations.

† The Comparative Mortality Figure represents the corrected Death-rate in each town compared with the death-rate at all ages in England and Wales during 1911, the latter being taken as 1000.

Towns, in the order of their Corrected Death-rates, 1911.	Factor for Correction for Sex and Age Distribution.*	Crude Death-rate.		Corrected Death-rate.		Comparative Mortality Figure, 1911.†
		Average 1906–10.	1911.	Average 1906–10.	1911.	
Cols.	1.	2.	3.	4.	5.	6.
Leicester	1·0671	13·80	13·29	14·73	14·18	971
Burton-on-Trent	1·0747	13·46	13·23	14·47	14·22	974
Barrow-in-Furness	1·1364	13·52	12·52	15·36	14·23	975
Newport (Mon.)	1·0804	14·90	13·35	16·10	14·42	988
Portsmouth	1·0267	14·06	14·05	14·44	14·43	988
Southampton	0·9942	13·62	15·19	13·54	15·10	1,034
Cardiff	1·0875	14·44	14·02	15·70	15·25	1,045
Grimsby	1·0709	14·62	14·41	15·66	15·43	1,057
Derby	1·0778	13·92	14·32	15·00	15·43	1,057
Bristol	1·0273	13·86	15·12	14·24	15·53	1,064
Smethwick	1·0940	13·24	14·26	14·48	15·60	1,068
London	1·0511	14·88	15·04	15·64	15·81	1,083
West Bromwich	1·0085	15·80	15·76	15·93	15·89	1,088
Tynemouth	1·0326	17·20	15·43	17·70	15·93	1,091
Huddersfield	1·0728	15·34	15·00	16·46	16·09	1,102
Wolverhampton	1·0343	15·82	16·36	16·36	16·36	1,121
Halifax	1·0836	15·16	15·16	16·43	16·43	1,125
Bradford	1·1053	15·32	14·89	16·93	16·40	1,127
Merthyr Tydfil	1·0603	18·28	15·54	19·38	16·48	1,129
Rhondda	1·1000	15·54	15·03	17·09	16·53	1,132
Birkenhead	1·0658	15·44	15·64	16·46	16·67	1,142
Warrington	1·0772	16·96	15·48	18·27	16·68	1,142
Rochdale	1·1060	16·76	15·09	18·54	16·69	1,143
Plymouth	0·9750	16·28	17·16	15·87	16·73	1,146
Rotherham	1·0343	15·98	16·25	16·53	16·81	1,151
West Ham	1·0695	15·54	15·77	16·62	16·87	1,155
Nottingham	1·0535	16·24	16·06	17·11	16·92	1,159
Gateshead	1·0541	16·14	16·09	17·01	16·96	1,162
Stockport	1·0804	17·12	15·74	18·50	17·01	1,165
Hull	1·0250	16·10	16·67	16·50	17·09	1,171
Aston Manor	1·1087	14·00	15·50	15·52	17·18	1,177
West Hartlepool	1·0980	15·30	15·65	16·80	17·18	1,177
Walsall	1·0590	15·44	16·24	16·35	17·20	1,178
Stockton-on-Tees	1·0486	16·62	16·55	17·43	17·35	1,188
Newcastle-on-Tyne	1·0772	16·50	16·11	17·77	17·35	1,188
Sheffield	1·0778	16·30	16·12	17·57	17·37	1,190
Swansea	1·0728	16·50	16·19	17·70	17·37	1,190
Bury	1·1196	16·02	15·86	17·94	17·76	1,216
Leeds	1·0908	16·00	16·37	17·45	17·86	1,223
Bolton	1·1308	15·90	15·86	17·98	17·93	1,228
Birmingham	1·0759	16·62	16.78	17·88	18·05	1,236
South Shields	1·0584	17·04	17·08	18·04	18·08	1,238
Blackburn	1·1308	16·30	16·12	18·43	18·23	1,249
Salford	1·1047	18·22	16·65	20·13	18·39	1,260
Preston	1·0940	17·94	16·86	19·63	18·44	1,263

* See footnote on p. 425. † Ibid.

Towns, in the order of their Corrected Death-rates, 1911.	Factor for Correction for Sex and Age Distribution.*	Crude Death-rate.		Corrected Death-rate.		Comparative Mortality Figure, 1911.†
		Average 1906–10.	1911.	Average 1906–10.	1911.	
Cols.	1.	2.	3.	4.	5.	6.
Sunderland . . .	1·0314	18·60	17·95	19·18	18·51	1,268
Manchester . . .	1·1135	18·12	16·99	20·18	18·92	1,296
Dewsbury	1·0993	17·50	17·25	19·24	18·96	1,299
Bootle	1·1013	17·26	17·63	19·01	19·42	1,330
Wigan	1·0973	18·28	17·87	20·06	19·61	1,343
St. Helens	1·0836	17·02	18·17	18·44	19·69	1,349
Oldham	1·1245	18·62	17·62	20·94	19·81	1,357
Burnley	1·1273	17·70	17·97	19·95	20·26	1,388
Middlesbrough . .	1·0888	19·74	19·42	21·49	21·14	1,448
Liverpool	1·0702	19·60	19·96	20·98	21·36	1,463
Stoke-on-Trent . .	1·0791	18·48	19·89	19·94	21·46	1,470

* See footnote on p. 425. † Ibid.

If the corrected death-rate in each town be compared with the death-rate at all ages in England and Wales taken as 1000, it gives a number known as the *comparative mortality figure*, as shown in the last column of the preceding table. These figures may be expressed in another way, by saying that after correction has been made for differences of age and sex distribution, the same number of people that gave 1000 deaths in England and Wales in 1911, gave 1223 in Leeds, 971 in Leicester, and 1263 in Preston. Or we can say that in 1911 the recorded death-rate for the whole of England and Wales was 14·60; and the recorded death-rate for Blackburn is 16·12 with its factor for correction as 1·1308. Then $16{\cdot}12 \times 1{\cdot}1308 = 18{\cdot}23$ as the corrected death-rate for Blackburn and $\frac{18{\cdot}23}{14{\cdot}60} \times 1000 = 1249$ as its figure of comparative mortality.

Infantile Mortality.—The calculations of infant and child mortalities demand special remark; particularly as it is by no means uncommon to find them worked out on the population, or on the number of deaths at all ages. The proper, the most simple, and most accurate way is rather to utilize the birth returns, and calculate out the ratio of deaths of infants under one year to the number of actual births in the latter half of the preceding year and the first half of the current year. The greatest care should be given to child mortality, or the death-rate of those under five years of age, as it constitutes an important and instructive index of health conditions. In 1918, the proportion of deaths of infants under one year of age to 1000 registered births was 97 or 9·3 per

cent. below the average of the ten preceding years. For London the infantile mortality rate in 1918 was 108 per 1000 births. The rate differs widely in different counties and towns; the general rule being that the rate is lowest in the purely agricultural, and highest in the mining districts, and in those with textile industries.

County Borough.	Deaths under One Year per 1,000 Births.	County Borough.	Deaths under One Year per 1,000 Births.
Total County Boroughs	109	Norwich	107
		Manchester	107
Bournemouth	57	Newcastle-on-Tyne	108
Canterbury	58	Leicester	109
Southport	60	Walsall	110
Oxford	62	Birkenhead	110
Worcester	64	Tynemouth	111
Exeter	65	Salford	112
East Ham	67	Preston	112
Hastings	72	Dewsbury	112
Brighton	72	Bury	112
Lincoln	73	West Bromwich	112
Southend-on-Sea	73	Merthyr Tydfil	113
Eastbourne	74	Stockport	113
Bath	74	Stoke-on-Trent	113
Reading	75	Darlington	114
Portsmouth	76	Blackpool	114
Croydon	77	West Ham	115
Gloucester	83	Bootle	117
Ipswich	83	Rochdale	119
Chester	89	South Shields	120
Wallasey	89	Oldham	121
Wakefield	90	Gateshead	123
Newport (Mon.)	90	Wigan	123
Bristol	92	Nottingham	123
Southampton	92	Blackburn	124
Northampton	92	Bradford	125
Coventry	93	Dudley	125
Swansea	95	Liverpool	126
Derby	95	Halifax	126
Plymouth	97	Burnley	126
Birmingham	97	Hull	127
Wolverhampton	97	St. Helens	127
York	97	Sheffield	128
Great Yarmouth	99	Grimsby	129
Burton-on-Trent	99	Carlisle	130
Warrington	101	Sunderland	131
Huddersfield	101	Leeds	133
Barrow-in-Furness	102	Rotherham	136
Smethwick	103	Middlesbrough	148
Cardiff	104	Barnsley	162
Bolton	106	West Hartlepool	167

The chief causes of infantile mortality, common to every locality, are briefly: premature birth, congenital defects, hereditary tendencies, inexperience and neglect of mothers, industrial conditions, improper food, and overlaying.

The table on p. 428 shows the infant mortality per 1000 registered births in the County Boroughs of England and Wales in 1918. From this it will be seen that the highest infantile mortality was in Leeds, Rotherham, Middlesbrough, Barnsley, and West Hartlepool.

A very frequent source of error in vital statistics is made in calculating the mean death or other rate of two populations or communities; these are often spoken of as *combined death-rates*. The error usually arises from failing to take into account the proportion which the two populations or groups bear to one another. Thus suppose two towns each contain 30,000 inhabitants, and have respectively mortalities of 22 and 16, their mean or combined death-rate would be $\frac{22+16}{2}$ or 19. But suppose one of the towns has 42,000 inhabitants and the other 18,000, and have respectively the above mortalities, their combined death-rate will then not be the mean of their two separate death-rates, but as follows:—

One town of 42,000 people with a death-rate of 22 per 1000	=	924	deaths.
" " 18,000 " " " 16 "	=	288	"
or 60,000 people give		1212	deaths,

and $\frac{1212 \times 1000}{60,000} = 20{\cdot}2$, the true combined death-rate per 1000.

Death-rates are said to be largely influenced by the birth-rate, and by densities of population. With regard to the influence of the birth-rate upon the death-rate much controversy has prevailed. To a great extent this has been unnecessary, and has arisen from a misconception as to the true meaning of the relation between the birth- and death-rates. If we imagine a population in which there has been a high birth-rate for one or more years, it is clear such must contain a larger proportion than usual of young children, and inasmuch as the death-rate of young children is higher than that of all others except the aged, the general death-rate of that population will be raised; but this condition is to a large extent counterbalanced by the fact that a high birth-rate implies the presence in that particular population of a large proportion of persons of the child-bearing age, that is, of an age-period when the mortality is unusually low. So, again, if the high birth-rate be continued for any length of years, it means not only a large proportion of children and of persons at reproductive ages, but also

of young adults, among whom a low rate of mortality also prevails.

The real influence of the birth-rate upon the death-rate, therefore, is not one which can be well expressed as a low birth-rate causing a low death-rate, or a high birth-rate producing a high death-rate, but rather that the average age of a population governs the death-rate, and that the lower the mean age of the living, the lower should be the death-rate, and, by inference, that the death-rate really controls the birth-rate, because the lower it is the more chance is there of there being a large proportion of persons at the child-producing ages. If a high death-rate follows a high birth-rate, it reasonably suggests an excessive infantile mortality; very often low death-rates and low birth-rates co-exist, but it does not follow that the one is necessarily caused by the other.

The influence exerted by density of population on mortality and death-rates has lóng been recognized. The density may be either expressed as so many persons to a square mile or as acres to a person. Farr found that the mortality increases with the density of a population; not in direct proportion to the density, but as their sixth root; while, according to Ogle, this influence of the density does not affect the mortality unless there be more than four hundred persons to the square mile. The practice of building back-to-back houses, so prevalent in Yorkshire and Lancashire, and without provision for through ventilation, illustrates very clearly the evil effects of crowding populations, and has been well sifted by the reports of Barry and Gordon Smith to the Local Government Board in 1888.

Increased density of population gives rise to filth conditions, to the more rapid spread of infectious diseases, phthisis, accident, and other evil conditions, the outcome of co-existent poverty and occupation. It is probably by and through these, rather than from mere overcrowding, that density of population in any way influences the death-rate of a community.

Causes of Death.—It is not sufficient to know the death-rate of a community; it is necessary to know and inquire what rates the different causes of death give when the deaths are distributed to their several classes. Although the death returns obtained from registrars are principally derived from certificates signed by either doctors or coroners, and, as such, should be clear statements of the precise cause of death, still even now the cause of death in many cases is both vague and ill-defined. Each year, however, shows improvement in this direction, with the result that the registration of death-causes is becoming gradually more and more accurate and complete.

The death-rate from zymotic or special febrile diseases is an important fact to be noted among all communities, as it furnishes a very popular standard as to their general healthiness. But it will readily be understood that it is liable to great fluctuations according to the greater or less prevalence of one or other of those diseases, with the result that a so-called mean zymotic death-rate is often of little value. Thus, say in a given community the zymotic death-rate be excessive owing to the epidemic prevalence of the two zymotic diseases, measles and whooping-cough. Owing to these diseases not being either usually or truly dependent upon defective sanitary conditions, their excessive prevalence, as evidenced by an increased zymotic death-rate, furnishes less clue as to the health-condition of the community than would an equally high zymotic mortality rate, owing to such diseases as diphtheria or enteric fever, which are more directly the expression of faulty sanitary states. For this reason the aggregate zymotic death-rate has now been abandoned by the Registrar-General.

Of late years the deaths from zymotic has shown a steady tendency to fall. The following are the death-rates from some of the principal diseases of this class in England and Wales during 1918, expressed per million persons living:—Enteric fever, 35 for males and 25 for females, or 30 for all persons; from small-pox only two deaths were recorded; measles, 289 for all ages, or 867 for ages under 15; scarlet fever, 29 for all ages, or 80 for ages under 15; whooping-cough, 296 at all ages, and 893 for ages under 15; diphtheria, 143 for all ages, and 418 for ages under 15; tuberculosis of the lungs showed a rate of 1343, or 7·6 per cent. of the death-rate from all causes.

The influence of age upon mortality rates is very marked in certain diseases. Thus, phthisis or consumption is at its lowest prevalence between the ages of 5 and 12, but increases up to 47 years of age, after which it lessens. Small-pox mortality is highest in the first and twenty-fifth years, while diarrhœa, whooping-cough, measles, and diphtheria all have their highest death-rates during the first few years of life. Cancer is a disease which appears rarely to affect the young, but tends to increase after 28 years of age. Diseases connected with the heart and circulatory system increase in their mortality rates from birth upwards. The total death-rate, and the death-rates from affections of the nervous system, lungs, and bladder, all appear to be at their lowest between the tenth and fifteenth years of life.

Occupation.—Modern investigations have thrown considerable light upon the influence which occupation has upon mortality. Some callings are much less favourable to health than others; some again, while being relatively healthy, are

dangerous. The chief circumstances which render certain employments more or less hurtful to health are, bad ventilation and overcrowding of workrooms; exposure to weather, or extremes of heat and cold; inhalations of vapours, gases, or metallic, mineral, or organic dust; overstrain, and mental anxiety; and intemperance. Many difficulties and fallacies underlie all comparative statistics of class mortalities, unless due allowance be made for the age at which such employments are followed, as well as the question of the class of person actually engaged, and the importance of differentiating between employer and employed.

The following table shows the comparative mortality amongst persons of various occupations, as gathered from the more recent statistics:—

Occupation.	Comparative Mortality figure.	Occupation.	Comparative Mortality figure.	Occupation.	Comparative Mortality figure.
Clergymen	524	Artists or architects	823	Silk workers	964
Gardeners	563	Coachmakers	824	Fishermen	967
Game-keepers	586	Milk sellers	832	Law clerks	970
Farmers	596	Drapers	845	Other occupied males	978
Railway engine-men	610	Jewellers	872	Shoemakers	984
Farm labourers	621	Gasworkers	878	Wool workers	984
Brick makers	653	Coal miners	885	Commercial travellers	988
Schoolmasters	665	Millers	890	Printers	994
Civil service clerks	723	Bricklayers, Masons	906	Druggists	999
Grocers	729	Cord makers	910	Tramway men	1013
Paper makers	730	Commercial clerks	911	Fishmongers	1013
Coal merchants	731	Engine fitters	913	Curriers	1015
Navvies	740	Hosiery makers	921	Paperhangers	1018
Ironmongers	741	Bakers	922	Tailors	1027
Ironstone miners	744	Indoor servants	927	India-rubber workers	1032
Lawyers	750	Stationers	931	Copper and tin smiths	1043
Tallow or soap makers	764	Bookbinders	934	Carpet makers	1044
Engine drivers, &c.	767	Blacksmiths	937	Chemical workers	1065
Maltsters	773	Stone quarriers	939	Plumbers, painters	1114
Tanners	774	Greengrocers	942	Cotton workers	1114
Sawyers	774	Saddlers	945	Dyers, bleachers	1114
Railway clerks	776	Lace makers	950	Slaters, tilers	1115
Messengers	791	Doctors	952	Hatters	1137
Cycle makers	797	Cabinet makers	956	Butchers	1148
Wheelwrights	808	Gas or lock fitters	957	Carmen	1153
Rlwy. guards, etc.	813	Tobacconists	962	Grooms	1157
Shipwrights	817	Lithographers	964		
Carpenters	820				

Occupation.	Comparative Mortality figure.	Occupation.	Comparative Mortality figure.	Occupation.	Comparative Mortality figure.
Gunsmiths	1181	Musicians	1261	General shop-keepers	1548
Wood turners	1181	Scissor or file makers	1315	Seamen	1646
Nail or chain makers	1187	Furriers	1332	Copper miners	1668
Hairdressers	1196	Bargemen	1333	Inn keepers	1781
Lead miners	1206	Chimney sweeps	1343	Hotel servants	1883
Brush makers	1216	Brewers	1393	Costermongers	2007
Coalheavers	1221	Dock labourers	1484	Tin miners	2131
Glass blowers	1260	Potters	1493	General labourers	2235

The comparative mortality figures as given in the foregoing table simply mean that, for any given occupation, there would be that number of deaths for every 1000 deaths in the general male population of similar numbers and identical age distribution.

If comparisons be made with corresponding statistics calculated on the census returns of 1891, it is found that the mortality in the main working period of life has declined by 16 per cent. Nearly all occupations have shared in this decline, for only six grades of workers show an increase of mortality; these are lace makers, hosiery manufacturers, copper miners, tin miners, general shopkeepers, and general labourers. The total number employed in these occupations amounts, however, to less than one-twentieth part of the total occupied male population above the age of 15 years. The recorded increase of mortality among lace and hosiery manufacturers is small, being one per cent. among the former and six per cent. among the latter. Among copper miners the increase is 13 per cent., but the number of these workers is inconsiderable. Tin miners are also few in number; their mortality shows an increase of 35 per cent. on the previous record. Among general shopkeepers the increase of mortality amounts to 26 per cent., and among general labourers to no less than 41 per cent. It is probable, however, that owing to more accurate statements of occupation under each heading the mortality figures in the two periods are hardly comparable; but, even now, the mortality in both these occupations is above the standard for all occupied males.

In attempting to judge the health of a community by statistical evidence, the greatest importance is attached to the following

points, namely: The total corrected death-rate, the zymotic death-rate, and the infant mortality. All these have been discussed, and the various sources of error connected with them explained. But, besides these, certain other evidence is usually considered, mainly as a test of the mean or average longevity of the population. This evidence consists of facts relating to what is known as "the mean age at death," "the probable duration of life," and "the expectation of life."

The **mean age at death** is of course obtained by adding up the ages of persons dying, and dividing this sum by the total number of deaths. In this country, the mean age of death averages 42 for males, and 45 for females. This fact is, however, an imperfect and crude test or index of longevity, simply because it is so largely affected by the birth-rate. If the birth-rate be high, there will be in consequence a greater proportion of infants or young children in the population. These we know have a relatively high death-rate, with the result that the average age at death will be proportionately reduced.

The **probable duration of life** is practically the age at which exactly half of any given number of children born alive will have died; or, in other words, there are equal chances of their dying before and after that age. It is sometimes spoken of as the equation of life, or *vie probable* of French writers. All these terms are more or less unfortunate, as there is a probability for every possible duration of life. Regarded strictly as defined above, the probable duration of life is of no great value as a test of longevity; it can only be obtained from what is called a life-table, and as so determined for England and Wales, gives the probable duration of life for each male 47 years, and for each female 52 years. The probable duration of life is often confounded with another statistical expression, called the *mean duration of life*, which is the probable or likely duration of life from birth, and, by French writers, called the *vie moyenne*. If we imagine an absolutely stationary population, that is, one in which age and sex distribution does not change, then, starting from birth, the mean duration of life would be identical with the mean age at death, and with the expectation of life as determined by means of life-tables. But such a stationary population is rare, and in an ordinary community, whose numbers are constantly being disturbed by migration or other causes, the mean duration of life really signifies the present age in years *plus* the probable duration of life after having attained a given age, and which is more commonly called the mean after lifetime, or expectation of life. For comparative purposes, it is often more convenient to employ the term mean duration of life as indicating the expectation

of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, expectation of life, must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has. Its estimation is made by means of what is called a Life Table, and which is nothing more than a table constructed from census figures on the basis of the number living and the number dying at each age. Such a table shows how many out of say a million persons supposed to be born at the same time will survive at the end of each year or term of years. The same table will also show the sum of the number of years which they live, and if this sum of these years be divided by the number living at any given age, the result will be the expectation of life for that given age.

Farr called a life-table a *biometer*, because it really represents "a generation of individuals passing through time," and measures the probabilities of life and death of this generation at birth, and of the survivors at each successive age-period, until the whole generation is extinct. In order to construct a life-table, it is necessary to have (1) particulars from a census return of the number, age, and sex-distribution of a population; (2) return of deaths for one or more years among this same population, grouped in the same ages or age-periods as have been adopted for stating the census population. A separate table is required to be constructed for each sex, and for this reason the death returns must be distinct for the two sexes.

A life-table can be constructed for either annual or quinquennial intervals; in most tables, an annual interval is adopted for the first five years, and after that five-year periods are taken. The first step is to calculate from the census returns the death-rate per 1000 living for each age or group of ages, and call this D. These deaths may be assumed to be evenly distributed over the whole age-period, so that half the deaths will occur in the first portion of the period, and the other half in the second portion; and the ratio of the final to the initial population is $\frac{1000 - \frac{1}{2}D}{1000 + \frac{1}{2}D}$, which, when simplified, becomes $\frac{2000 - D}{2000 + D}$.

For the construction of a hypothetical life-table, let us suppose that the mortality among infants in a given population is 100 for every 1000. It will be at once evident that if there be 1,000,000

babies born and living at the commencement of a given year, these will be reduced to 900,000 in the course of the year, and this number will commence the second year. Presuming that the data show that the death-rate among children in the second year of life is as high as 50 per thousand living, then applying the foregoing formula, we get $\frac{2000 - 50}{2000 + 50}$ or $\frac{1950}{2050}$ or 0·951019, and the 900,000 children at the beginning of the second year are reduced to 900,000 × 0·951219, or 856,097 at the beginning of the third year. In the same way, knowing the death-rates for the third, fourth, and fifth years of life, the actual numbers of children surviving at the end of those age-periods is calculated. Suppose now, by the end of the fifth year only 650,000 survive out of the original million, and we propose to continue constructing the life-table for quinquennial or five-year periods in place of annual intervals. The calculation is practically the same, substituting for the death-rate of each year the death-rate for each quinquennium. Presume the death-rate among persons aged 5 to 10 years to be 7, then applying the formula for the reduction of the population during this five-year period, we get $\left(\frac{2000 - 7}{2009 + 7}\right)^5$ or 0·965632, and at the end of this quinquennium, or by the end of the tenth year, the 650,000 will be reduced to 650,000 × 0·965632 = 627660. This calculation can be repeated for each five-year period until there are no more survivors left.

Such an ideal life-table will consist of a series of columns, in the first of which will be entered the various years of life or age-periods headed by the symbol x.

The second column would be marked D, or as it is sometimes written M_x. The entries in this column would be obtained by dividing the deaths during each year or age-period by the corresponding mean population, and represent the rate of mortality.

From the entries in the second column, those of the third or p_x column would be obtained. These represent the probability of living one year for each age or age-period, as calculated from the formula $p_x = \frac{2000 - D}{2000 + D}$.

The next column, l_x is obtained by multiplying the number living at the immediately preceding year by p_x. The entries in this column will represent the number surviving at each successive age, or, in other words, l_x represents the number who reach the precise age x.

The next column required in a life-table is one showing the

mean number living in each year of life, and technically called P Thus the mean number living in the tenth year $= \frac{l_9 + l_{10}}{2}$.

The next column in the table is known as the Q_x column. The number opposite any age in this column is the sum of all the numbers in the P_x column from that age to the end of the table, that is, until all the lives become extinct: and it shows, therefore, the aggregate number of years which the persons at each age in the table will live.

The last column is that marked E_x; in it, opposite each age, is placed the mean after lifetime, or expectation of life at each age. This is obtained from the formula $E_x = \frac{Q_x}{l_x}$.

The following table represents the headings of a typical life-table, prepared in accordance with the foregoing principles; it will serve to show a complete view of the results obtainable from a life-table. Each year of age should be inserted to make it complete, but in order to economize space, the intermediate years have been omitted.

Age of Age-Period. x.	Annual Mortality per Unit at Age x. D or M_x.	Probability of Living one Year from each Age p_x.	Number Born and Living at each Age. l_x.	Mean Population in each Year of Age. P_x.	Years of Life Lived at Age x and upwards. Q_x.	Mean afterLife-time at each Age x. E_x.
0	0·18326	0·83212	511,745	456,820	20,426,138	39·41
5	0·01369	0·98640	370,358	367,672	18,410,252	49·71
10	0·00563	0·99438	353,031	352,007	16,608,936	47·01
15	0·00519	0 99482	344,290	343,415	14,866,429	43·18
20	0·00832	0·99171	333,608	332,231	13,169,656	39·48
25	0·00920	0·99084	319,442	317,892	11,536,677	36·12
35	0·01105	0·98901	288,850	287,229	8,492,601	29·40
45	0 01554	0·98458	253,708	251,763	5,774,489	22·76
55	0·02485	0·97644	209,539	206,984	3,447,708	16·45
65	0·04698	0·95410	150,754	147,315	1,631,508	10·82
75	0·10391	0·90122	75,777	72,012	491,685	6·49
85	0·21966	0·80208	16,877	15,151	63,030	3·73
95	0·42035	0·65265	833	678	1,806	2·17
105	—	—	4	3	5	—

On this basis a number of life-tables have been constructed, the earliest being based on the population of England and Wales enumerated in 1841, and the deaths registered in the seven years 1838–44. The latest life-table for England and Wales is that issued from the Registrar-General's office by Tatham, and based on the death-rates for the ten years 1891–1900, and on the census

returns of 1901. The following table gives a portion of this life-table as issued in 1907 :—

Age x.	Chance of Living One Year from each Age. p_x		Of 1,000,000 Males born, the Number Surviving at each Age. l_x	Of 1,000,000 Females born, the Number Surviving at each Age. l_x	Of 1,000,000 of both Sexes born (508,770 Males and 491,230 Females).		Mean after Lifetime or Expectation of Life. E_x	
	Males.	Females.			The Number Surviving at each Age l_x	Population or Years of Life Lived, in and above each Year. Q_x	Males.	Females.
0	0·82814	0·85934	1,000,000	1,000,000	1,000,000	45,920,642	44·13	47·77
1	0·94681	0·95051	828,136	859,342	843,464	45,019,089	52·22	54·53
2	0·97917	0·97986	784,090	816,810	800,163	44,197,275	54·12	56·34
3	0·98682	0·98666	767,754	800,357	783,769	43,405,309	54·26	56·49
4	0·99030	0·99045	757,631	789,683	773,376	42,626,737	53·98	56·25
5	0·99282	0·99294	750,281	782,144	765,932	41,857,083	53·50	55·79
10	0·99786	0·99769	734,299	765,267	749,511	38,077,372	49·63	51·97
15	0·99695	0·99694	725,373	755,499	740,172	34,352,172	45·21	47·61
20	0·99543	0·99586	711,714	741,766	726,427	30,683,582	41·02	43·44
25	0·99432	0·99498	693,894	725,386	709,363	27,092,709	37·01	39·37
30	0·99329	0·99382	673,200	705,819	689,223	23,595,047	33·07	35·39
35	0·99103	0·99218	648,169	682,147	664,860	20,207,596	29·26	31·52
40	0·98810	0·99005	615,964	653,014	634,164	16,957,225	25·64	27·82
45	0·98519	0·98830	577,010	619,184	597,727	13,875,672	22·20	24·20
50	0·98064	0·98505	530,888	580,320	555,170	10,990,312	18 90	20·64
55	0·97432	0·97977	475,849	533,105	503,975	8,338.589	15·79	17·24
60	0·96404	0·97072	409,518	473,037	440,720	5,971,126	12·93	14·10
65	0·95031	0·95813	332,344	398,299	364,743	3,952,986	10·34	11·27
70	0·92788	0·93757	246,630	309,168	277,251	2,343,547	8·05	8·78
75	0·89460	0·90689	158,608	210,688	184,191	1,189,793	6·15	6·70
80	0·84800	0·86374	82,298	118,068	99,870	486,744	4·62	5·05
85	0·78642	0·80655	31,323	49,925	40,461	148,098	3·45	3·80
90	0·70814	0·73622	7,724	14,330	10,969	30,369	2·58	2·87
95	0·61719	0·65806	1,059	2,494	1,764	3,784	1·95	2·23
100	0·52092	0·58305	138	556	242	573	1·51	1·81

Having stated the data on which a life-table is based, and described the method of its construction, we are in a position to study the life-history of the persons to which it has reference. The essential points for such a study are the three following :—

(*a*) *The probability of living a given period for each age-period* in the two sexes separately. This is commonly written p_x, and equals, as we have already seen, $\dfrac{\text{number of survivors at end of period}}{\text{number living at beginning of period}}$.

Thus, by the above latest English life-table, at birth the probability of a male child living one year is $\frac{828,136}{1,000,000}$, or, the certainty of surviving to the end of the first year of life being taken as unity, the probability of his dying during the year is $\frac{1,000,000-828,136}{1,000,000}=0\cdot271864$. At 25, the probability of a male living five years by the same life-table is $\frac{673,200}{693,894}$, and the probability of his dying during the quinquennium is $\frac{693,894-673,200}{693,894}$ or $0\cdot02982$; and so on.

(*b*) *The number of survivors out of* 1,000,000 *children born* of each sex, at each succeeding year, or quinquennial period of life, until the whole number becomes extinct by death. The above table starts with a million boys and a million girls assumed to be born at the same time, and shows how many survivors there would be at each successive period. Thus, of 1,000,000 males born, 530,888 are still alive at the end of fifty years from birth; and of 1,000,000 females born, 580,320 survive to the same age.

(*c*) *The expectation of life*, or mean after lifetime, of males and females at the end of each given period. To find the expectation of life at any age x, the rule is, add together the years of life lived through by the whole of the life-table population after that age, and divide by the number of survivors at that age, or $E_x=\frac{Q_x}{l_x}$. Suppose it is required to find the expectation of life for males at the age of 35, on the basis of this English life-table. If we refer to that table, and add together the numbers surviving at each age later than 35, we obtain the figure 3,469,353, which is the number of complete five-year periods lived through by the whole of the life-table population after 35 years of age. These five-year periods equal 17,346,765 years, and as this number of years is lived by 648,169 males, the number of complete years lived by each male is 26·76 years. This result is known as the "curtate expectation of life."

In the above remarks we have confined our attention to the complete quinquennia of life, and have not taken into account that portion of lifetime lived by each person in the quinquennium of his death. In some instances this may be only a few months or days, in others one or more years; but it may be assumed with a fair degree of accuracy, taking one person with another, that the duration of life in the quinquennium of death will be half such a period, that is, 2·5 years. If we add this 2·5 to

the curtate expectation of life, the complete expectation of life is obtained. Thus, the complete expectation for males at $35 = 26{\cdot}76 + 2{\cdot}5 = 29{\cdot}26$ years. In life-tables where the age-periods are given in single years of life, the addition to be made to the curtate expectation will be $0{\cdot}5$ year. Usually, only the complete expectation of life is given in life-tables.

Recent statistical returns indicate that the expectation of life at birth has risen in the case of males to 51 years, and in that of females to 55 years. These increases are due largely to the lessened mortality in the first few years of life. The increased expectation of life at birth has risen by as much as ten years in the last generation, for both sexes.

Tests of Longevity.—These resolve themselves practically into attempts to measure the duration of life. The *expectation of life* or mean after lifetime has been explained and is identical with the "mean duration of life at birth," but the *mean duration of life* for any later age signifies the age in question plus the mean after lifetime at that age. In the absence of life-tables, the late Dr. Farr showed that the mean duration of life, or mean after lifetime, could be approximately calculated from the birth- and death-rates by the following formula, in which B = birth-rate and D = death-rate, while x = the expectation of life at birth.

$$x = \frac{2}{3} \times \frac{1000}{D} + \frac{1}{3} \times \frac{1000}{B}$$

Say a town has a birth-rate of 32 and a death-rate of 28 per 1000, then, applying this formula, we get

$$\frac{2000}{3D} + \frac{1000}{3B} \text{ or } \frac{2000}{84} + \frac{1000}{96} = 34$$

as the mean expectation of life at birth under those conditions.

Willich gives another formula, in which x = the expectation of life at any age a, between 25 and 75 years; then : $x = \frac{2}{3}(80 - a)$, and applying this, say for calculating the expectation of life at 53 years of age, we get $\frac{2}{3}(80 - 53) = x$, or 18 years.

For comparative purposes, it is often more convenient to employ the term "mean duration of life" as indicating the expectation of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, "expectation of life," must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows

the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has.

The *mean age of the living*, obtained by dividing the sum of the ages of the population at the census by the number of the population, has been proposed as a test of longevity. At best it is unreliable and, as Newsholme says, in insanitary areas the mortality may spend itself chiefly among young children; apart from this, immigration is a circumstance which especially disturbs the mean age of the living and renders it most untrustworthy as an index of longevity.

Value of Statistical Facts.—We have now discussed the chief kinds of statistical material generally at the disposal of the sanitarian, but before closing the subject, it is necessary to indicate the chief sources of fallacy in statistics, and the general limits within which they may be used. In an ideal mass of statistics, the facts must (1) be all correctly observed; (2) they must be of the same kind and order; (3) they must be all localized both in regard to time and place; (4) they must be sufficiently numerous to give correct averages, and extend over sufficient length of time. It will be at once obvious that these various essentials are not easy to obtain. It has already been explained that while it is easy enough to ascertain correctly the numbers of a people during a census year, it is less simple to do so during intermediate years. Similarly, differences of degree or intensity, causation or virulence of diseases, render their comparison, by reducing their statistics to the same order and kind, extremely difficult. So, too, the importance of localizing statistics, both in respect of time and place, is made clear by pointing out the absurdity of attempting to construct a particular disease-rate for some health resort from the deaths of persons occurring there from that special affection. The fourth essential for an ideal statistical series is well expressed in the mathematical statement that the error diminishes as the square root of the number of observations; in other words, the smaller the total number of facts, the larger will be the relative percentage of errors displayed by them, and the larger the number of facts collected the smaller will be the margin of error.

The *mean* or *average* has been described as being a number which lies between the highest and lowest of a series of numbers, and has a definite dependence upon the whole of the series. The terms mean and average are often used synonymously; regarded mathematically, there are several kinds of means. Thus, the simple average, or *arithmetic* mean of four numbers, such as a, b, c, d, is conveniently written as $\frac{a+b+c+d}{4}$, but their

geometric mean would be $\sqrt{abcd}$, while their *harmonic* mean stands thus: $\dfrac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$, and their *quadratic* mean is—

$$\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}$$

Of course if the terms of the series of numbers are unequal, then the quadratic mean will be the highest, next the arithmetic, and then the geometric and harmonic means; but if all the terms of the series are equal, then their means are equal too. The chief practical question in vital statistics is not so much the value of a true average, or arithmetic mean, or even the probable value of a fixed quantity, but rather the value of a variable quantity. If we consider any measurable character in a group of people, we find that there is variation, and the first essential is some means of describing this variability. For this purpose, biometricians use the *standard deviation*, a function usually expressed by the symbol σ.

Mathematically, standard deviation can be defined by the following expression, $\sigma = \sqrt{\dfrac{n_1a_1^2+n_2a_2^2+n_3a_3^2+n_4a_4^2}{N}}$ . . .; in which n_1, n_2, etc., are the numbers of individuals having the same measurements, and a_1, a_2, etc., are the number of units separating each group value from the mean value of the whole sample N. Suppose in a sample of 100 poppy capsules 15 individuals had 5 stigmatic bands, 30 had 6, 30 had 7, 20 had 4, and 5 had 3, then the arithmetic mean of the whole would be 5·6 stigmatic bands, and the standard deviation would be

$$\sigma = \sqrt{\frac{15\ (0{\cdot}6)^2 + 30\ (0{\cdot}4)^2 + 30\ (1{\cdot}4)^2 + 20\ (1{\cdot}6)^2 + 5\ (2{\cdot}6)^2}{100}}$$

or $\sqrt{1{\cdot}54} = 1{\cdot}24$.

The standard deviation is a concrete number which measures the way the frequencies are distributed in terms of the unit of measurement. Since the greater is the distance between any group value and the mean, the larger is the number by which the total of individuals in the group is multiplied, the standard deviation affords us a knowledge as to how the observations are distributed about the mean; the more they are scattered the larger will be the standard deviation.

Probable Error.—The theory of the probable error and its connection with the standard deviation is developed from the normal curve of error, and gives that value (p) of x which divides the part of the normal curve representing positive errors into two

equal portions. Its proof is, however, of a complicated nature, and unsuitable for insertion in the present work.

It is clear that the magnitude of the probable error is a criterion of the weight to be attached to any statistical constant, and any statistical constants unaccompanied by their probable errors are of no scientific importance. Since the exact degree of improbability to be regarded as decisive is a matter of individual opinion, the general rule followed by statisticians when considering probable errors is that unless a result exceeds the expected by two or three times the probable error it is not safe to assume that the particular case differs from the expected result. This value is of considerable use in statistical work, and it may be of interest to see its application to an example or so. Assume a simple case wherein it is wished to find the probable error of an event happening mp times when m trials are made and p is the probability of the event happening and q of its failing. The standard deviation is $\sqrt{mpq}$, and the probable error is $0{\cdot}67449\sqrt{mpq}$. Take another case: If 51,350 out of 100,000 children proved to be males in a certain township, would it be safe to base on the statistics any theory connected with the variation from the usual probability that the usual number of male children born is to the number of females born as 1050 is to 1000? Clearly the expected result is 51,220; therefore the probable error is $0{\cdot}67449\sqrt{100{,}000\frac{1050}{2050}\cdot\frac{950}{2050}}$, or $\pm\ 103{\cdot}9$. The difference between the actual case and the expected result was 130, and as this is but one and a quarter times the probable error, no definite conclusions can be based on the divergence from the result. Had the number of cases been ten million, then the probable error would have been 1039 and the actual difference 13,000. This would have been sufficient evidence for the conclusion that the ratio 1050 to 1000 did not fit the particular case.

It is unnecessary here to go into further detail as to the calculation of probable errors. Formulæ have been obtained for the errors of all important constants, among which may be mentioned the following: *The probable error of the mean* is $\pm\ 0{\cdot}67449 \times \frac{\text{standard deviation}}{\text{square root of the number of variates}}$. The *probable error of the median* is $\pm\ 0{\cdot}84535 \times$ standard deviation $\div$ square root of the number of variates. The *probable difference between two averages* of which the probable errors are known is the square root of the sum of the squared probable errors. The *probable error of the standard deviation* is

$$\pm 0 \cdot 67449 \frac{\text{square root of twice the number of variates}}{\text{standard deviation}}.$$

Recognizing that the probable error is a pair of values lying one above and the other below the value determined, we can say that there is an even chance that the true value lies between these limits.

CHAPTER XII.

SANITARY LAW.

It is not proposed in the following pages to completely review and summarize the whole of the law bearing upon the Public Health, but only to consider so much of it as appears requisite to be known by the head of a household. While the main basis of so-called sanitary law, as now in force in the different parts of the United Kingdom, are the various Public Health Acts, notably those of 1867 (Scotland), of 1875 (England and Wales), of 1878 (Ireland), and of 1891 and 1899 (London), there are in addition a large number of other Acts of Parliament which, in various ways, strengthen or otherwise modify the foregoing. This condition of affairs naturally renders the whole subject of sanitary law a matter of some complexity.

For the purposes of this chapter, in place of analyzing each Act separately, we have deemed it more convenient to consider the general effect of legislation as a whole upon certain matters of sanitary importance, and to limit that summary to the law as applicable to England, Wales, and London.

By the Ministry of Health Act, 1919, a Ministry of Health came into existence, and it has all the powers and duties of the old Local Government Board, of the Insurance Commissioners, of the Board of Education with respect to the health of expectant mothers, of nursing mothers and children under five years of age, and as to the medical inspection and treatment of children and young persons, of the Privy Council in respect of the Midwives Acts, 1902 and 1918, and as to infant life protection under the Children's Act, 1908.

In order to economize space, certain abbreviations will be employed; these and the full titles of the chief Acts of Parliament bearing upon the Public Health, and referred to in the following abstract, are given below:—

B.A. Board of Agriculture.
B.M.A. Butter and Margarine Act, 1907.
C.B.A. Canal Boats Acts, 1877–84.
C.D. (Animals) A. Contagious Diseases (Animals) Acts, 1878 and 1886.
C.P.A. Cleansing of Persons Act, 1897.
D.C.M.O. Dairy, Cowshed, and Milk-shop Orders, 1885–86 and 1899.
F.W.A. Factories and Workshops Acts, 1878, 1895, 1901, and 1907.
H.T.P.A. House, Town Planning Acts, 1909 and 1919.
H W.C.A. Housing of the Working Classes Acts, 1885, 1890, 1900, and 1903.
I.D.N.A. Infectious Disease Notification Act, 1889.
I.D.P.A. Infectious Disease Prevention Act, 1890.
I.H.A. Isolation Hospital Acts, 1893 and 1901.
L.B.A. London Building Act, 1894.
L.C.C. (G.P.) A. London County Council (General Powers) Act, 1890.
L.G.A. Local Government Acts, 1888, 1894, and 1899.
M.H. Ministry of Health.
M.A. Margarine Act, 1887.
M.D.A. Milk and Dairies Acts, 1915 and 1920.
M.M.A. Metropolitan Management Act, 1855.
M.O.H. Medical Officer of Health.
M.S.A. Merchant Shipping Act, 1894.
M.W.A. Metropolitan Water Acts, 1852 and 1871.
N.B.A. Notification of Births Act, 1907, and Extension Act, 1915.
N.I.A. National Insurance Act, 1911.
O.S.A. Open Spaces Act, 1887.
P.H.A., 1875 and 1896. Public Health Act (England).
P.H. (Amend.) A. Public Health Act Amendment Act, 1890.
P.H. (Lond.) Public Health (London) Act, 1891.
P.H. (Fruit-pickers) A. Public Health (Fruit-pickers) Act, 1882.
P.H. (Foods) A. Public Health Food Regulations Act, 1907.
P.H. (Interments) A. Public Health (Interments) Act, 1879.
P.H.P.A. Public Health Ports Act, 1896.
P.H. (Water) A. Public Health (Water) Act, 1878.
P.H. (S.) A. Public Health (Scotland) Act, 1867.
P.H. (I.) A. Public Health (Ireland) Act, 1878.
R.P.P.A. Rivers Pollution Prevention Acts, 1876 and 1893.
S.A. Sanitary Authority.
S.F.D.A. Sale of Food and Drugs Acts, 1875 and 1907.
S.F.D. (B.) A. Sale of Food and Drugs Act, 1899.
V.D.A. Venereal Diseases Act, 1917.

Of these Acts, the Public Health Amendment Act, 1890, and the I.D.P.A. of 1890, and the Notification of Births Act, 1907, are alone "adoptive" at the discretion of a sanitary authority.

Local Sanitary Areas and Authorities.—The whole of England and Wales, outside the City of London, is divided into (*a*) administrative counties and (*b*) county boroughs. By the L.G.A., 1894, the administrative counties are divided into county districts, some of which are urban and others rural districts. For sanitary administration, the county boroughs and municipal boroughs are deemed to be urban districts, and constitute urban sanitary dis

tricts; while the rural districts, each consisting of one or more parishes, are rural sanitary districts.

In every administrative county there is a county council, who may appoint one or more Medical Officers of Health, and who have various other powers and duties in connection with the sanitary administration and supervision of the county, more particularly of complaining under sec. 299 P.H.A., 1875, in cases where a S.A. is not doing its duty, and of enforcing the provisions of the Rivers Pollution Prevention Act, the Isolation Hospitals Acts, the Diseases of Animals Act, etc.

In county and other boroughs the mayor, aldermen, and burgesses, acting as the municipal council, are the urban sanitary authority. In urban districts, other than county and municipal boroughs, the district council constitutes the sanitary authority: but they may appoint committees, consisting either wholly or partly of their members, for the exercise of sanitary powers. An U.D.C. administers the P.H.A., 1875, the P.H.A. (Amend.) A., 1890, the P.H. (Water) A., 1878, if applied by the M.H., the R.P. Prev. A., the Factory Act, Housing of Working Classes Acts, the Inf. D.N. Acts, the Inf. Dis. Prev. Act, 1890 (if adopted), the S.F.D.A., the Horseflesh Act, the Margarine Act, the D.C.M. Orders, the Canal Boats Act, Infant Life Protection Act and Local Acts.

A rural district council has all the powers, duties, and liabilities of an urban sanitary authority under the P.H.A. and other Acts. In addition, the M.H. may, by Order, direct that any provisions of any Act which are applicable to urban districts only, shall apply to rural districts as well. Under this category come various clauses in the P.H. (Amend.) A and the H.W.C.A. The P.H. (Water) A. applies only to rural sanitary districts. A rural district council may apply to the M.H. to have all the powers of an urban district council conferred upon them.

While in the provinces there is practically one S.A. acting for each district, it is otherwise in the Metropolis. Under L.G.A., 1899, with the exception of the City of London, every part of the administrative County of London is situated in some one of the metropolitan boroughs established under the Act. In the City and Port of London the City Corporation are the S.A. In the metropolitan boroughs the borough councils are the S.A., certain powers being transferred from the County Council. These powers can only be exercised within the borough, and refer chiefly to the registration of dairymen, to the removal of obstructions, and sky signs, etc. While certain powers of the County Council will also be exercised by the borough councils.

Definitions.—There are certain definitions of terms in the

various sanitary Acts which give to those terms meanings which are not the same as the common meaning. The more important of these definitions are the following:—

Building. This word includes wooden structures on wheels, also those without foundations, but resting simply on the ground. Under I.D.N.A., 1889, the term "building" applies to boats, vessels, ships, tents, vans, sheds, and other similar structures used for human habitation.

House. Though not absolutely defined, the term "house" is so extended as to include schools, factories, and other buildings in which persons are employed. For a structure to be a "house" it is not necessary that persons reside in it.

Under the Town Planning Act, 1909, "house" includes part of a house, and a house does not cease to be a dwelling when no longer inhabited. A "dwelling" is a place in which a person passes the night.

Owner. Under the Public Health Acts, the term "owner" means the person who, for the time being, receives the rack-rent of the lands or premises in connection with which the word is used, whether on his own account, or as agent or trustee for any other person, or who would so receive the same if such premises were let at rack-rent. By "rack-rent" is meant the rent that is not less than two-thirds of the full net annual value of the property.

Under Part II. Housing of the Working Classes Act, the owner of a property is held to be any person or corporation who has at least a twenty-one years' interest in it.

Drain means any drain of, and used for the drainage of, *one* building only, or premises within the same curtilage, and made merely for communicating therefrom with a cesspool, or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

Sewers include sewers and drains of every description, except drains to which the word "drain," as above defined, applies. In other words, a sewer is a drain receiving the drainage of two or more buildings, and may be an open channel, such as a polluted watercourse, as well as an underground culvert. The situation has been complicated by certain judicial rulings and interpretations of the adoptive P.H. (Amend.) A., 1890, which imply that, under sec. 19 of this adoptive act, the common pipe is to be deemed a sewer only if all the houses belong to one owner and that, if they belong to more than one owner, then the combined drain is a drain repairable at the owners' expense, and not a sewer repairable at the expense of the S.A. Fig. 80 will explain the meaning of these definitions. The diagram represents four

houses, the drains of which pass out at the back of each into the garden or yard. Under the definition as given in sec. 4 of P.H.A., 1875, the pipe AD is a drain only as far as its junction with the pipe from the second house, after which it is a sewer, as much as the public sewers EF and GF. The application of the rulings under sec. 19 of the Act of 1890, will be obvious, according as to whether the houses are owned by one or more owners. The sec. 19 of the adoptive Act of 1890 speaks of a

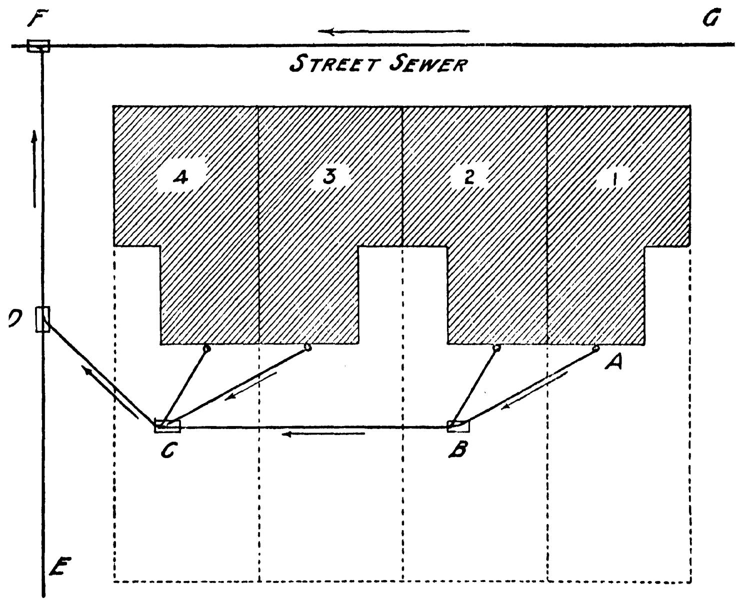

FIG. 80.—Diagram illustrating what is a "drain" and what is a "sewer."

"single private drain," and the whole difficulty seems to hinge on what this expression really means, when read in conjunction with the definition of the words "drain" and "sewer" as contained in sec. 4 of the Act of 1875.

Our own view of the case is that the majority of the rulings have been wrong, owing to too much importance having been attached to the mere definitions as given in sec. 4 P.H.A., 1875, and sufficient attention not having been given to the Act as a whole, especially when read in conjunction with the Amending Act of 1890. To understand the point it is desirable to appreciate the general nature of the drainage system which the 1875 Act designed to establish. By sec. 21 of the Act, an

owner or occupier is, under certain conditions, entitled to cause his drains to empty into the sewers of the S.A., and by sec. 23 that body may require the owner or occupier of any house within its district which is without a drain "sufficient for efficient drainage," to make a covered drain or drains to open into a public sewer, if within 100 feet of the site of such house, or to empty such drain into such covered cesspools or places as the S.A. may direct. Again, under sec. 25 of the Act, it is unlawful in any urban district to erect any house or rebuild any house, or to occupy such newly erected or rebuilt house until covered drains be constructed in such manner as the S.A. approves. Next, we find sec. 40 of the Act of 1875 enacting that these drains must be constructed and kept so as not to be a nuisance, and sec. 41 prescribes the machinery by which the owners of houses may be compelled to discharge the obligations imposed on them as regards drains. It is clear from these sections that so long as the drainage was efficient, it was immaterial whether the owner of two or more houses caused the drainage to go into sewer or cesspool by separate pipes or by several pipes uniting into one. This conduit or conduits would be in the ordinary meaning of language a drain, and, being situate in whole or in part on the premises of the person who constructed, would be "single" and "private"; and, even if not made to carry off drainage of his own houses, would belong to his premises and consequently to be kept in good order by him. In the case of two or more owners providing for the drainage of their houses on a similar plan, the common pipe would belong to their premises, would be "single" and "private," and clearly maintained by those owners whose houses it served. It is clear from these sections what were the objects, in respect of drains, which the framers of the Act of 1875 had in view, and that, when they defined "drains," they contemplated the pipes which secs. 23 and 25 required the owners to provide or see were provided. There appears to be no justification to assume that the definition as given in sec. 4 was intended to raise a drain to the dignity of a sewer simply because it joined another drain. In fact, the Amending Act of 1890 would seem to have been passed in order to correct the view that where a common conduit carried to a sewer the drainage of two or more houses belonging to different owners, that common conduit was no longer a drain. Its real object was to bring within the reach of sec. 41 of the P.H.A., 1875, that class of drainage conduit which, by force of the strained definition of "drain," had begun to be placed outside its operation, and to transfer to the shoulders of owners of houses, which this class of conduit served, the burden of maintaining them. In other words, that class of conduit or pipe which secs.

23 and 25 of the 1875 Act compelled owners to provide or see were provided. Therefore, in regard to this vexed question of what is a "drain," we may say that, irrespective of the definition, a pipe, in order to be a single private drain under sec. 19 of the P.H. (Amend.) Act, 1890, must be such a pipe as owners could be required to provide under secs. 23 and 25 of the P.H.A., 1875. A necessary corollary to this is that a pipe to be a "drain" under the P.H.A., 1875, must have as termini at one end one "building or premises within the same curtilage," and at the other end "a cesspool or other receptacle for drainage, or a sewer into which the drainage of two or more buildings occupied by different persons is conveyed." While the word "sewer" includes sewers and drains of every description except drains to which the word "drain" interpreted as aforesaid applies, and also except drains "vested in or under the control of any authority having the management of roads and not being a local authority under this Act."

Canal. Under the C.B.A., 1877 and 1884, the term "canal" includes any river, lake, water, or inland navigation "being within the body of a country, whether it is or is not within the ebb or flow of the tide."

Canal Boat. This includes any and every vessel, however propelled, used for conveyance of goods along a canal, as above defined, but does not include a ship registered under the Merchant Shipping Act, 1894, unless the M.H. orders otherwise, which it may do on the representation of a S.A. or any of its inspectors.

Bye-laws and Regulations.—In respect of certain matters, and under certain conditions expressly stated in the various Acts dealing with the Public Health, sanitary authorities may make bye-laws, having the force of law. These bye-laws are intended rather to supplement than to summarize, vary, or supersede the express provisions of the statute law. All bye-laws made by a S.A. under and for the purpose of the Public Health Acts must be under its common seal; and any such bye-law may be altered or repealed by a subsequent bye-law made pursuant to the provisions of the Acts. But no bye-law is of effect, if repugnant to the laws of England, or to the provisions of the Acts. A S.A. may, by any bye-laws made by it, impose such reasonable penalties as it thinks fit, not exceeding £5 for each offence, and, in the case of a continuing offence, a further penalty not exceeding 40*s*. per each day after written notice of the offence; but all such bye-laws imposing any penalty must be so framed as to allow of the recovery of any sum less than the full amount of the penalty. Bye-laws do not take effect unless and until they have been

confirmed by the M.H., who have power to allow or disallow the same as they think proper. The bye-laws, when confirmed, must be printed and hung up in the office of the S.A., and a copy of them must be delivered to any ratepayer of the district who applies for them (see P.H.A. 1875, secs. 182 to 185).

Some bye-laws must be made by a local authority; there are others which may be made by both urban and rural authorities, and others also which urban sanitary authorities alone are empowered to make. In the greater number, the power to make them is permissive.

Regulations differ somewhat from bye-laws, because with few exceptions they do not require the approval of the M.H. They may be simply passed as a resolution at a meeting of the authority, and may be amended or rescinded at a subsequent meeting. In certain cases, as, for instance, under sec. 125, P.H.A., 1875, relating to the removal to hospital of infected persons brought by ships, a regulation, just like a bye-law, has to be approved by a superior authority, and its breach involves liability to a money penalty. The same is the case in regard to regulations made by a S.A., under the regulations as to Food Act, 1907, as to the importation, storage, preparation, and distribution of food.

Urban Sanitary authorities are empowered to make bye-laws, in respect of the following:—

Common Lodging Houses (P.H.A., 1875, sec. 80).
Cleansing and Scavenging and Nuisances (P.H.A., 1875, sec. 44).
Tenement Houses and Lodging Houses (P.H.A., 1875, sec. 90).
Seamen's Lodging Houses (M.S.A., 1894, sec. 214).
New Streets and Buildings (P.H.A., 1875, sec. 157, and Part III. P.H. (Amend.) A., 1890).
Slaughter Houses (P.H.A., 1875, sec. 169).
Markets and Fairs (P.H.A., 1875, sec. 167).
Offensive Trades (P.H.A , 1875, sec. 113).
Hop and Fruit Pickers (P.H.A., 1875, sec. 314, and P.H. (Fruit-pickers) A., 1882).
Tents and Vans (H.W.C.A., 1885, sec. 9).
Mortuaries and Cemeteries (P.H.A., 1876, sec. 141, and P.H. (Interments) A., 1879).
Open Spaces (P.H.A., 1875, sec. 164, and Open Spaces Act, 1887).
Buildings provided under H.W.C.A., 1903.
Means of Escape from Fire (F.W.A., 1901, sec. 15).

The Municipal Corporations Act, 1882, sec. 23, gives power to municipalities or borough councils to make bye-laws for the suppression and prevention of nuisances, not already punishable in a summary manner by any other Act in force throughout the borough. County councils have similar powers under the Local Government Act, 1888, sec. 16.

Urban authorities can further make bye-laws under the Housing of the Working Classes Act, 1890, for the regulation

of all buildings provided under that Act or the Acts which it supersedes.

Rural sanitary authorities have similar powers for making bye-laws in respect of the following: (1) Private Scavenging; (2) Common Lodging-houses; (3) Tenement Houses and Seamen's Lodging-houses; (4) Hop and Fruit-pickers; (5) Tents and Vans; (6) Mortuaries; and (7) Under the Housing of the Working Classes Act, 1890. Further, by adopting portions of the P.H. (Amend.) A., 1890, which are not expressly limited to urban districts, rural sanitary authorities can make certain bye-laws as to new and old buildings. The M.H. may confer on them any other powers as to bye-laws which the Public Health Acts give to urban authorities (P.H.A., 1875, sec. 276).

Every sanitary authority *must* make bye-laws as to common lodging-houses; every urban sanitary authority *must* do the same as to slaughter-houses; the exercise of power as to other bye-laws is optional.

The London County Council has power to make bye-laws for the regulation of the plans, levels, width, surface, inclination and materials of new streets and roads; for the plan and sites of buildings; as to the dimensions, form, construction, cleansing and repairing of pipes, drains and traps connected with sewers; and as to the construction, ventilation and cleansing of sewers (L.B.A., 1894, sec. 164, and certain unrepealed clauses of the Metropolitan Local Management Acts).

Also under the P.H. (Lond.) A., 1891, for regulating the conduct of offensive trades, and the structure of the premises (sec. 19). For prescribing the times for removal of any fæcal or offensive matter in or through London, so as to avoid the creation of a nuisance (sec. 16). As to the closing of cesspools and privies, the removal and disposal of refuse, and as to the duties of the occupier of any premises in connection with house refuse (idem). As to water-closets, earth-closets, ash-pits, cesspools, receptacles for dung, and the proper accessories thereof in connection with buildings (sec. 39). Also as to tenement houses (sec. 94). The power to make bye-laws under section 19 is permissive, but under secs. 16, 39, and 94 is compulsory. Under the L.G.A., 1899, it is the duty of each borough council to enforce the bye-laws and regulations in force for the time being.

The Metropolitan sanitary authorities, under the same Act, *must* make bye-laws for the control of nuisances arising from snow, ice, salt, dust, rubbish, ashes, carrion, fish, or filth in the streets; or from offensive matters running from any manufactory, brewery, slaughter-house, or dung-hill; for the prevention of keeping animals on any premises in such place or manner as to be a

nuisance or dangerous to health; and as to the paving of yards and open spaces in connection with dwelling-houses (sec. 16). For the keeping of water-closets supplied with sufficient water for their effective action (sec. 39). For the cleansing and protecting of all cisterns, tanks, etc., used for storing water for domestic purposes, drinking, or the manufacture of beverages (sec. 50).

Similarly, in rural districts, the district council is the rural sanitary authority. Where the number of councillors of any such district is less than five, the M.H. may, by Order, nominate such number of persons as are necessary to make up that number from owners or occupiers of property situated in the district. The persons so nominated are entitled to act and vote as members of the rural S.A., but not further or otherwise. An alternative procedure is for the M.H. to order the affairs of the district to be administered by the district council of an adjoining district. Each rural district council has all the powers, duties, and liabilities, as a rural S.A., as were exercised by the old boards of guardians. They have also the same powers for appointing committees as have the district councils of urban districts other than boroughs (L.G.A., 1894, sec. 56).

The M.H. may, by a General Order, confer upon rural district councils such urban powers as they think fit; this is in addition to their right, under the P.H.A., 1875, to grant urban powers for particular areas, which right, under the 1894 Act, may be exercised by the Board on the application of the county or parish council concerned.

All district councils have the charge of highways. They also administer the Acts relating to petroleum and infant life protection. and the licensing of knackers' yards—a duty hitherto carried out by quarter sessions. In large rural districts, the district council may appoint parochial committees for outlying parishes to act as a resident subordinate authority, and as its agents. If such exist, the members of these committees must be selected from the members of the parish council. These parochial committees are completely under the control of the rural S.A., which made them, and have no jurisdiction beyond the places for which they are formed.

By the L.G.A., 1894, *parish councils* and *parish meetings* are constituted in rural districts. By sec. 8 of that Act, the parish council has power to utilize any well, spring, or stream within its parish, and power to drain, clean, cover, to remedy the condition of ponds and stagnant pools; also to acquire or hire land for allotments, make official representation to the district council under the Allotments Act; or to the M.O.H. under the Housing of the Working Classes Act, in regard to unhealthy areas and

obstructive or unhealthy dwellings; or to the M.H., for granting of urban powers for their parish or any part of it. The district council may delegate to the parish council any powers which it may delegate to a parochial committee under the Public Health Acts. A parish council may complain to the county council if the rural district council have failed to provide or to maintain sufficient drainage or water supply for the parish, or to enforce any provision of the P.H.A. 1875.

Apart from expenditure under adoptive Acts, such as the Public Health Amendment Act, 1890, the parish council must not incur expenses involving more than a *6d.* rate in any year, nor more than a *3d.* rate without the consent of the parish meeting. They may raise money on loan, but only with the approval of the parish meeting, the county council, and the M.H. The parish meeting has the exclusive power of adopting certain optional Acts, including the above-named, the Burial Acts, the Baths and Washhouses Acts, the Lighting and Watching Act, 1833, and the Public Improvements Act, 1860.

In order to simplify sanitary administration, boundaries of local sanitary areas are adjusted so as to prevent intersection of those which define counties, county districts, unions, and parishes. Small rural parishes are grouped into workable units for parish council purposes, but each has its own parish meeting. Although by the Act of 1894 some few sanitary powers are given to parish councils, those powers in no way derogate from the sanitary obligations of a district council, which is the true rural sanitary authority.

Although the powers conferred on urban and rural sanitary authorities are in many respects identical, they are not entirely so. By sec. 276, P.H.A., 1875, the M.H. may, on application of a rural S.A., or of persons rated to the relief of the poor, whose assessments amount to one-tenth of the nett rateable value of the district, declare, by Order, any provision of that Act in force in an urban district to be in force in such rural district or part thereof. In like manner the Private Street Works Act, 1892, and the P.H. (Amend.) Act, 1890, may be put in force in the whole or part of any rural sanitary district. In amplification of the foregoing, by sec. 25 (7) of the L.G.A., 1894, similar powers may be exercised by the M.H., on application of a county council, or with respect to any parish or part thereof, on application of the parish council. Experience has shown that the provisions of the P.H.A., 1875, hitherto most frequently put in force, are secs. 42, 44, 157, and 158, relating to cleansing and watering of streets, and making of bye-laws as to nuisances and new buildings. Other sections which are occasionally put in force

are 112 and 114, relating to offensive trades, and secs. 169, 170, which regulate slaughter-houses.

The same authorities *may* make bye-laws for the removal to hospital, or detention therein, of persons suffering from infectious disease (sec. 66). For preventing the fouling of tents, vans, sheds, and similar structures used for human habitation, and the spread of infectious disease by the inhabitants thereof (sec. 9). In relation to tenement houses, under sec. 8 of H.W.C.A., 1885, these same authorities must also enforce any bye-laws made by the London County Council under secs. 16, 39, and 94 of the P.H. (Lond.) A., 1891.

In the City of London, similar powers are vested in the Corporation under the City of London Sewers Acts, 1848 and 1851, the Public Health (Lond.) Act, 1891, the Gardens in Towns Protection Act, 1863, the Metropolitan Open Spaces Act, 1877 and 1881, and the Open Spaces Act, 1887.

Under the Dairies Order, 1885 and 1899, any S.A. may make regulations for any of the following purposes: (*a*) for the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation, drainage, cleansing, and water supply of dairies, and cowsheds; (*c*) for prescribing precautions to be taken by purveyors of milk against infection; (*d*) for securing the cleanliness of milk-stores, milkshops, and milk vessels, used for containing milk for sale.

A S.A., subject to approval by the M.H., may make Regulations for the removal to hospital, and detention there as long as necessary, of all persons who may be brought within their district by either boat or ship, and who may be infected with an infectious disease (P.H.A., 1875, sec. 125). They have also power to make Regulations for the management of places provided by them for making post-mortem examinations ordered by a coroner (sec. 143).

The M.H. has power to make Regulations under secs. 130 and 134, P.H.A., 1875, in relation to cholera, and other dangerous infectious diseases. These powers are extended under P.H.A., 1896.

From time to time, the M.H. has prepared and issued "model bye-laws" to serve as guides to sanitary authorities when seeking to frame bye-laws. As these models have been very generally adopted, subject to occasional modifications, by various local authorities, a summary of them will be given under their proper heading, where their provisions may help to a better appreciation of the requirements of the several Public Health Acts. The following have been issued up to the present time:—

Private Scavenging.	Houses let in Lodgings.	
Prevention of Nuisances.	Cemeteries.	
Common Lodging Houses.	Mortuaries.	
New Streets and Buildings.	Hop-pickers.	
Markets.	Offensive Trades, including those of a	
Slaughter-houses.	Blood-boiler.	Leather-dresser.
Hackney Carriages.	Bone-boiler.	Tanner.
Horses, etc., let for hire.	Fell-monger.	Fat-melter.
Pleasure-boats.	Soap-boiler.	Glue-maker.
Pleasure-grounds.	Tallow-melter.	Size-maker.
Public Bathing.	Tripe-boiler.	Gut-scraper.
Baths and Wash-houses.	Blood-drier.	

Supplementary to these model bye-laws, various regulations in regard to the management of mortuaries and cemeteries have been issued by the Home Secretary.

Cleansing and Scavenging.—By sec. 42, P.H.A., 1875, every S.A. may, and when required by the M.H. shall undertake or contract for the removal of house refuse and cleansing of privies, ashpits, etc. Further, every urban S.A. and every rural S.A. invested by the M.H. with the requisite powers may, and when required by the Ministry shall themselves undertake or contract for the proper cleansing and watering of streets for the whole or any part of their district. All refuse, so collected, shall be the property of the local authority, to be sold or otherwise disposed of. Moreover, if Part III. P.H. (Amend.) A., 1890, has been adopted, the S.A. may, under sec. 26 (2) of that Act make bye-laws imposing on occupiers duties to facilitate the removal of refuse. Any person obstructing removal to be liable to a penalty not exceeding £5, except as regards refuse, etc., which the occupier intends to employ for his own use, unless he meanwhile suffers it to become a nuisance. If the S.A., having themselves undertaken or contracted for the removal of house refuse from premises, or the cleansing of earth-closets, privies, ashpits, and cesspools, neglect, without reasonable excuse, to remove any refuse within seven days of receiving a remonstrance from the occupier, they shall be liable to pay to him 5*s*. for each further day's neglect (sec. 43, P.H.A., 1875). An urban S.A. may, by sec. 45 of the same Act, provide receptacles and places for the temporary deposit of the matter collected.

By sec. 44, P.H.A., 1875, the S.A. has power to make bye-laws imposing the duty of cleansing footways, pavements, ashpits, privies, cesspools, and removing house refuse when they themselves do not contract or undertake to do the same, and may make bye-laws for the prevention of nuisances from accumulations of snow, filth, ashes, etc., and from the keeping of animals.

Model bye-laws have been issued for the prevention of these nuisances. (*a*) They require the house refuse to be removed

once at least every week, and prescribe the same interval for the cleansing of every ashpit and privy, and every earth-closet furnished with a movable receptacle for fæcal matter, and with suitable means or apparatus for the frequent and effectual application of dry earth to such matter. Where the receptacle is fixed, the time allowed is three months, and a like period is prescribed for the cleansing of cesspools. (*b*) So far as nuisances from snow are concerned, the occupier of any premises must clear away snow from the footways and pavements adjoining his premises, as soon as possible after it ceases to fall. (*c*) The refuse from any premises shall only be removed in a suitable covered receptacle or carriage, and if removed from premises within 20 yards of any dwelling, place of business, or public building, only between 7 a.m. and 9 a.m. from November to February, and between 6 a.m. and 8 a.m. from March to October. Refuse must not be deposited upon any road, and any refuse accidentally falling upon a road must be immediately gathered up and the place cleansed. (*d*) No load of filth must be deposited for more than 24 hours within 100 yards of any street, dwelling, public building, or place of business. Night soil deposited for agricultural purposes upon land within 100 yards of a street, dwelling, etc., and not deodorized, must at once be dug or ploughed into the ground. (*e*) Swine must not be kept within 100 feet of any dwelling, nor cattle where they can pollute water likely to be used for drinking, domestic, or dairy purposes, or for manufacturing drinks. The same prohibitions apply to the storage of dung. Premises wherein are kept any swine, cattle, horses, etc., must be provided with proper receptacles for manure, and with efficient drainage; the receptacle must be water-tight, covered, and entirely above the level of the ground, and it must be cleansed at least once a week; the drain must be properly constructed and kept in order at all times, so as to convey all liquid filth to a sewer, cesspool, or other suitable receptacle.

If the M.O.H. or two medical practitioners certify that any house or part thereof is so filthy as to endanger health, or that the whitewashing and purifying thereof would tend to prevent infectious disease, the S.A. may require the owner or occupier to cleanse, etc., and in his default may themselves do what is necessary (P.H.A., 1875, sec. 46).

Sec. 47 of the same Act prohibits not only keeping of swine in dwelling-houses so as to be a nuisance within an urban district, but also suffering stagnant water to lie in cellars or dwellings 24 hours after written notice from the S.A., and allowing contents of privies and cesspools to overflow or soak out, on a penalty not exceeding 40*s*., and a daily penalty not exceeding 5*s*. after notice,

and authorizes the abatement of the nuisance by the S.A. at the occupier's expense. Moreover, a sanitary inspector in an urban district may give notice to the owner of any offensive accumulation of matter, or to the occupier of the premises whereon it exists, to have it removed within twenty-four hours, failing which the S.A. may remove the same (sec. 49). An urban authority may give public notice requiring the periodical removal of manure from mews, and other public premises, and enforce the same under penalty (sec. 50).

In cases where Part III. P.H. (Amend.) A., 1890, is in force, by sec. 27 of the same, the S.A. has powers for keeping common courts and passages clean, apportioning the expenses incurred to the occupiers of adjacent premises.

In the Metropolis, the provisions for cleansing and scavenging under the P.H. (Lond.) A., 1891, are somewhat more stringent than those of the P.H.A., 1875, which controls the main actions of sanitary authorities in the provinces. By secs. 29 and 30 of the London Act, the S.A. *must* cleanse streets, footpaths, cess-pits, earth-closets, and privies. They *must* remove house refuse at proper intervals, and trade refuse also, if required to do so, on payment. As to what is or is not *trade* refuse shall, on complaint of either party, be determined by a petty sessional court, such decision being final (sec. 33 (2)). The S.A., further, may undertake the collection of manure and other refuse, on request; or may by order, require periodical removals by owner (sec. 36).

Sec. 16 (2) of the London Act empowers the county council to make bye-laws (*a*) for prescribing the times for removal of fæcal or other offensive matter through London, and for providing that the vessel or carriage therefor is properly constructed so as to prevent any nuisance; and (*b*) as to the closing and filling of privies, removal of refuse generally, and as to the duties of the occupiers in relation to facilitating the removal of it by the scavengers of the S.A. Further, a constable may arrest without warrant and take before a justice any person found committing an offence against such bye-laws, and who refuses to give his true name and address. Swine may not be kept in London within forty yards of a street or public place, nor be allowed to stray into any public place. A court may prohibit the keeping of any animal in any specified place shown to be unfit for the purpose (sec. 17).

Sewers and Disposal of Sewage.—By the P.H.A., 1875 (sec. 13), it is enacted that all sewers, except certain private sewers are vested in the S.A. of the district. The exceptions mentioned in the section are (1) Sewers made by a person or persons for his or their profit; (2) sewers made and used for

draining or improving land under any local or private Act, or for irrigation; (3) sewers under any commissioners of sewers appointed by the Crown. The S.A. may purchase (sec. 14), or construct (sec. 15) sewers. They must provide such sewers as are necessary for effectually draining their district, having, by sec. 16, powers of taking them through, across, or under lands and streets. Sec. 308 of the Act provides for compensation for damage, to be ascertained by arbitration. The sewers must be so constructed, covered, ventilated, and kept as not to be a nuisance or injurious to health, and must be properly cleansed (sec. 19). The performance of these duties by a S.A. can be enforced on complaint by individuals (sec. 299), while further powers, in this respect, are given by secs. 16 and 19 of the L.G.A., 1894, to county councils, on complaint by a parish council of a defaulting rural sanitary authority.

Under sec. 7, Rivers Pollution Prevention Act, 1876, every S.A. must give facilities for factories to drain into sewers, but provision is given for the protection of sewers from injurious matters such as anything which may impede the flow of their contents, any chemical refuse, waste steam, or water or liquid heated above 110° F., by secs. 16 and 17, P.H. (Amend.) A., 1890. The restrictions imposed by secs. 32, 33, and 34 of the P.H.A., 1875, on the execution of sewerage works by a S.A. outside its own district, involve the giving of a public notice, and in case of objection, the work not to be commenced without sanction of the M.H., who may appoint an inspector to make inquiry and report.

For the protection of the sewers of an urban sanitary authority, sec. 26, P.H.A., 1875, provides a penalty for unauthorized buildings over them; and secs. 150 and 151 give power to the S.A. to compel the sewering of private streets, subject to any byelaws the authority can get confirmed by the M.H. Powers are given by sec. 27 of the same Act for the treatment and disposal of sewage, but sec. 17 expressly insists that such disposal of sewage must not be into streams, unless purified before discharge; this latter section, however, needs to be read in connection with the Rivers Pollution Prevention Acts, 1876 and 1893, which give a certain amount of protection to sanitary authorities in respect of the pollution of streams and rivers by sewage channels used, constructed, or in process of construction at date of passing of the Act of 1876. Secs. 28, 29, and 30 of the P.H.A., 1875, further give power to the S.A. to deal with land appropriated to sewage purposes, to contribute to works executed by others for the disposal of the sewage, and to agree for communication of sewers with sewers of adjoining districts.

The incidence of the charge of sewage and other public sanitary works in urban districts is usually made by a general district or borough rate. In rural districts, the incidence of charge of expense of sewerage and other sanitary works are not made on the entire district, but constitute a separate charge on parishes or parts of parishes for which the works have been carried out, and the areas liable to contribute are termed "contributory places" (sec. 229). There are four kinds of contributory places: (1) a rural sanitary authority may, subject to approval by the M.H., constitute any portion of its area a "special drainage district" for the purpose of charging thereon exclusively the expenses of sanitary works, the cost of which is not spread over the entire district, and thereupon such area becomes a "contributory place;" (2) where no part of a parish is situate in a special drainage district, or in an urban sanitary district, the entire parish is a contributory place; (3) where no part of a parish is in an urban sanitary district, but part of it is in a special drainage district, the part not in a special drainage district is a contributory place; (4) where part of a parish is in an urban sanitary district, and part in a rural sanitary district, so much of it as is not in an urban district or special drainage district is a contributory place (sec. 229).

In the Metropolis, outside the city, the county council are the local authority for the purposes of the main sewerage and disposal of the sewage of London, while the borough councils are the local authorities for the purpose of the sewerage and drainage, other than the main sewerage. The powers of the county council, as regards main sewerage are derived from the Metropolis Management Act, 1885, taken in conjunction with a similar Act of 1862, and the Metropolitan Main Drainage Act, 1858.

While the main sewers are to be constructed and kept so as not to be a nuisance, the county council has power to declare sewers to be main sewers, and to take jurisdiction over sewerage and drainage matters belonging to the boroughs, also to control the borough councils in the construction of sewers, etc., by means of bye-laws. The general powers of the London County Council in respect of sewerage and disposal of sewage are very similar to those of the sanitary authorities in the provinces under the P.H.A., 1875. As relates to procedures for the prevention of floods, the powers of the county council, by inheritance from the Metropolitan Board of Works, are derived from the Metropolitan Management (Thames River Prevention of Floods) Amendment Act, 1879. All sewers, etc., within the City are vested in the Corporation, who have full power over them and all drains communicating with the public sewers, under the City of London Sewers Act, 1848.

By the Metropolis Management Act, 1855, sec. 68, all sewers, other than those now vested in the county council and the City Corporation, are vested in the borough councils, who from time to time must repair, maintain, alter, or extend as may be necessary; but no new sewers can be made in the administrative county of London without the approval of the county council. The powers given by the above provisions are extended in certain cases to areas outside the Metropolis by sec. 58 of the Metropolis Management Act, 1862. The Act of 1855 (secs. 73 to 75) further provides for the ventilation, trapping, cleansing, inspection, and proper connection of drains with sewers on the part of the sanitary authorities; while sec. 202 of the same Act gives the local authorities power to make bye-laws as to drains. For the purposes of their sewers, and for other purposes of the Metropolis Management Acts, every vestry or district board has the same power as the county council to purchase lands. These powers of purchase, however, are not compulsory (secs. 151, 152).

House Drainage, Water-Closets, Privies, etc.—Every sanitary authority, by secs. 22 to 25 P.H.A., 1875, has power to enforce drainage of undrained houses, and in certain cases to close existing drains on condition of providing others. These drains must lead to the public sewer if there be any within 100 feet of the site of the house; if not, to a covered cesspool in such position (not under a house) as the S.A. may direct. Failing compliance, the authority may carry out the work and recover in a summary manner the expenses incurred from the owner, or may by order declare the same to be "private improvement expenses." These private improvement expenses may be made payable by instalments with interest. They may, moreover, be levied on the occupier, whereas the expenses, if incurred summarily, will only be recoverable from the owner. It occasionally happens that owing to the delay in construction of sewers, houses have been supplied with cesspools and effectual drains leading thereto. In those cases the S.A. are under no obligation to pay the costs of drains necessary for enabling the house to discharge its sewage into the new sewers. Where the sewer is in the same sanitary district as that in which the premises are situate, the owner or occupier, upon giving due notice and complying with the regulations of the authority as to the mode in which the communication is to be made, is entitled to carry drains into the public sewer. In places where Part III. P.H. (Amend.) A., 1890, has been adopted, by sec. 18 of that Act, the owner or occupier has a right to require the S.A. to make the communication at his cost. Where the sewer is in another sanitary district, the communication must be made on such terms and conditions as may be agreed upon between

the owner or occupier and the S.A. to whom the sewer belongs.

Where any drain or cesspool is a nuisance, or injurious to health, the S.A. may take proceedings to remedy the matter either under sec. 41, P.H.A., 1875, or under the provisions of the same Act relating to nuisances. All the foregoing provisions apply to existing houses and drains without regard to the date of their construction, in both urban and rural districts.

In urban districts, and in rural districts, or contributory places endowed with urban powers by sec. 276, P.H.A., 1875, not only may *no* house be built, or rebuilt after having been pulled down to or below the ground floor, or be occupied after having been built or so rebuilt until proper covered drains have been constructed and duly connected with either a sewer or cesspool, as above indicated, to the satisfaction of the S.A. (P.H.A., 1875, sec. 25), but the authority may make bye-laws as to the mode in which connections between drains and sewers are to be made (sec. 157). This 157th section of the 1875 Act is only of limited extent, as it provides that no bye-law made under it shall affect any building erected in any place which, on August 11, 1875, was included in an urban sanitary district before the Local Government Acts came into force in such place, or any building erected in any place which, on that date, was not included in any urban sanitary district, before such place became constituted or included in an urban district, by virtue of any order of the M.H. subject to this enactment. Nor might any bye-law made under the section apply to buildings belonging to railway companies, and used for the purposes of such railways under any Act of Parliament. In places where Part III. P.H. (Amend.) A., 1890, has been adopted, sec. 23 of this same Act has extended the operation of this 157th section of the 1875 Act to buildings erected before the time mentioned and to rural sanitary districts. Rural S.A.s can therefore now, by adopting this part of the 1890 Act, obtain these very important powers throughout their districts without the intervention of any order of the M.H.

The law relating to privies, water-closets, excrement and refuse disposal resembles that relating to house drainage inasmuch as it is contained partly in statutory enactments applicable to both urban and rural sanitary districts, and partly in bye-laws applicable only to urban districts and to those rural sanitary districts or contributory places to which it has been specially applied by order of the M.H. The general statutory enactments in regard to these matters of excrement and refuse disposal are contained in the P.H.A., 1875, secs. 35 to 45, and practically amount to the following:—

It is unlawful to erect any house without a sufficient water-closet, earth-closet or privy, and an ashpit with proper doors and coverings; and the same must be provided for any existing house on the order of the S.A., who may require a separate closet for each house (secs. 35, 36, 37). The S.A. may order sanitary conveniences in factories where persons of both sexes are employed (sec. 38), while the Coal Mines Regulation Act, 1887, sec. 74, makes the same provision applicable to parts of mines above ground in which women and girls are employed. Every S.A. must see that all drains, closets, ashpits, and cesspools are properly constructed and kept (P.H.A., 1875, sec. 40); while urban sanitary authorities may provide public urinals, closets, or receptacles for refuse (idem. 39–45). On the written application of any person that any drain, closet, ashpit, or cesspool is a nuisance, the S.A. may, by writing, empower their surveyor or inspector, after giving 24 hours' notice, to enter the premises and open the ground; if any defect is found, the S.A. must serve notice upon the owner or occupier to do the necessary work, but if there is no defect the authority must close the ground and make good any damage (P.H.A., 1875, sec. 41).

Under Part III. P.H. Acts Amendment Act, 1907, local authorities have fuller powers in regard to these matters, notably right of entry for purposes of inspection *on the report of one of its officers*; further they have power to order such number of closets in a domestic building as they shall deem necessary to the size of the building. They also have power to deal with any urinal or sanitary convenience opening on to a public street, and to insist on the provision of urinals in public houses or places of refreshment or amusement On the report of one of its responsible officers a S.A. is authorized to apply the smoke or coloured water test (not water under pressure) to drains, but the consent of the owner or occupier must be given or an order of a Court of Summary Jurisdiction must be obtained.

There have been issued a series of model bye-laws relating to the various matters for which bye-laws may be made by a S.A. under the foregoing provisions. Their general provisions are sufficiently indicated in the following summary:—

Drainage.—Damp sites must be drained by earthenware field pipes properly laid to a suitable outfall, but not directly communicating with any sewer, or cesspool, or drain containing sewage. Rain pipes must be provided to carry away all water falling on the roof without causing dampness of the walls or foundations. The level of the lowest story must be such as to allow of the construction of a drain sufficient for the drainage of the building communicating with a sewer at a point above the centre of the

sewer. All drains for sewage must be made of impervious pipes 4 inches or more in internal diameter, laid with a proper fall in a bed of concrete, and with water-tight joints. Every drain inlet not intended for ventilation must be trapped. No drain conveying sewage must pass under a building unless no other mode of construction is practicable; in that case it must be laid in a direct line for the whole distance beneath the house, and must be embedded in and covered with concrete 6 inches thick all round, and must be laid at a depth below the surface at least equal to its diameter, and lastly, must be ventilated at each end of the portion beneath the building. The main drain must be trapped at a point within the curtilage, but as distant as practicable from the building. Branch drains must join other drains obliquely in the direction of the flow.

There must be at least two untrapped ventilating openings into the drains, according to one of the following alternative arrangements:—(1) One opening consists of a shaft or disconnecting chamber opening at or near the ground level, and situated as close as possible to the trap specified above, but on the house side of it; the other opening is a pipe or shaft carried from a point as far distant as possible from the said trap, that is, as near as possible to the head of the drain, vertically upwards in such manner and to such height (in no case less than 10 feet) as to prevent any escape of foul air into any building; but (2) if more convenient, the relative positions of these openings may be reversed, the shaft being placed near the trap, and the opening near the ground level at the head of the drain. The ground-level opening must have a grating, with apertures equal in total area to the sectional area of the drain. The pipe or shaft at the other end of the drain (whether used as a soil-pipe or not) is required to have a sectional area equal to that of the drain, and in no case to be less than 4 inches; all bends and angles are to be avoided as far as practicable.

No drain inlet is permitted within a building except the inlet necessary for a water-closet. Every soil-pipe must be at least 4 inches in diameter, must be placed outside the building, and must be continued upwards in full diameter without bends or angles, to such a height and such a point as to afford a safe outlet for sewer air. This height and point will usually be above the highest part of the roof of the building to which the soil-pipe is attached, and, where practicable, not less than 3 feet above any window within 20 feet measured in a straight line from the open end of such soil-pipe. There must be no trap between the soil-pipe and the drain to which it leads, nor in any part of the soil-pipe, except such as may be necessary in the construction

of the water-closet. The waste-pipe from a slop sink must conform to the same requirements as a soil-pipe. The waste-pipe from any other sink, bath, or lavatory, the overflow-pipe from any cistern and from any "safe" under a bath or water-closet, and every pipe for conveying waste water, must be taken through an external wall and must discharge in the open air over a channel leading to a trapped gully grating at least 18 inches distant.

Water-closets must have a window opening directly into the external air, and measuring 2 feet by 1 foot clear of the frame; and, in addition to the window, adequate means of constant ventilation by air-bricks, air-shafts, etc. Such closets, if within the building, must adjoin an external wall. The water must be supplied to a water-closet by means of a special cistern. The apparatus must be suitable for effectual flushing and cleansing of the basin; the basin must be made of non-absorbent material, and of such shape and capacity as to receive and contain a sufficient quantity of water, and to allow all filth to fall free of the sides directly into the water. "Containers" and "D traps" are forbidden.

Earth-closets are subject to the same conditions as water-closets so far as regards position, lighting, and ventilation. Proper arrangements must be made for the supply of dry earth, and its effectual and frequent application to the excreta; also for convenience of scavenging, and for exclusion of rainfall and drainage. The receptacle for excreta, whether fixed or movable, must be so constructed as to prevent absorption or escape of the contents, and to exclude rainfall and drainage; if fixed, its capacity must not be greater than may suffice for three months, nor in any case greater than 40 cubic feet, and it must in every part be 3 inches above the ground. In the case of earth-closets placed inside houses, the maximum limit of size may with advantage be reduced to 2 cubic feet.

Privies must not be erected within 6 feet of a dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, nor otherwise in such a position as to entail danger of the pollution of such water. Privies must be built so as to admit of convenient scavenging, without carrying the contents through any dwelling, public building, or place of business. There must be an opening for ventilation at the top; the floor must be paved, and raised 6 inches above ground in all parts, with a fall of half an inch per foot towards the door. The receptacle may be fixed or movable. If movable, as in pail-closets, the floor of the area beneath the seat must be flagged or asphalted, and

raised 3 inches above the ground level, and all the sides of the said area must be made of flag, slate, or brick, at least 9 inches thick, and rendered in cement. If the receptacle is fixed, it must be in every part 3 inches above the ground level, and its capacity not exceeding 8 cubic feet, presuming that the scavenging will be done weekly: suitable means or apparatus must be provided in connection with the privy for the application of ashes, dust, or dry refuse to the filth deposited; and the receptacle must be so constructed that the contents may not at any time be exposed to rainfall or to the drainage of any waste water or liquid refuse from any adjoining premises, while at the same time conveniently accessible for scavenging; the materials and construction must be such as to prevent any absorption by any part of it of any filth deposited therein, or any escape by leakage or otherwise of its contents. It must in no way be connected with a drain.

Cesspools must not be constructed within 50 feet of any dwelling, public building, or place of business, nor within 100 feet of any water likely to be used for drinking or domestic purposes, or for manufacturing drinks, or otherwise in such a position as to entail danger of pollution of such water. Cesspools must be so constructed and placed as to conveniently admit of scavenging and cleansing without carrying the contents through any dwelling, public building, or place of business. They must not be connected with any sewer. They must be covered over by an arch or otherwise, and adequately ventilated; they must be constructed of brick in cement, rendered inside with cement, and with a backing of at least 9 inches of clay.

Ash-pits must not be constructed within 6 feet of any dwelling, public building, or place of business, nor within 50 feet of any water likely to be used for drinking or domestic purposes, nor otherwise in such a position as to entail danger of the pollution of such water. Ash-pits must be so placed and constructed as to conveniently allow of scavenging without carrying the contents through any dwelling, public building, or place of business. The capacity must not exceed 6 cubic feet, or such less capacity as may suffice for a period not exceeding one week. The walls must be of flag, slate, or brick, at least 9 inches thick, and rendered inside with cement; the floor must be flagged or asphalted, and raised at least 3 inches above the ground level. The ash-pit must be roofed and ventilated, and provided with a door so arranged as to allow of the convenient removal of the contents, and to allow also of being closed and fastened. The ash-pit must not be connected with any drain.

In the Metropolis, in regard to all the foregoing matters, the

London County Council, by sec. 39 (1) of the P.H. (Lond.) A., 1891, are empowered to make bye-laws, which it is the duty of every S.A. in London outside the City to enforce and observe. Bye-laws made by the county council under this Act do not, however, extend to the City; but in that area analogous bye-laws can be made by the Corporation, who, as before stated, are the local authority. These bye-laws, whether made by the county council or by the City Corporation under the London Act of 1891, are subject to the provisions of secs. 182 to 185 of the P.H.A., 1875, as already explained in connection with bye-laws made by any S.A. in the provinces (see p. 440). In their main provisions the bye-laws in force in the administrative county of London and in the City accord closely with those suggested as models.

The obligations and powers of a S.A. in London in relation to house drainage and the removal of refuse are very similar to those of a sanitary authority in other parts of the country. A new house *must* have "one or more water-closets, as circumstances may require," with proper water supply, trapped soil-pan, and other accessories. The same applies to all houses, irrespective of date, under notice from the S.A. (P.H. (Lond.) A., sec. 37). A privy or earth-closet may only be substituted if the available sewerage and water supply is insufficient for a water-closet. Any person who may think himself aggrieved by any notice or act of the S.A. may appeal to the county council, whose decision is final. These appeals are governed by sec. 126 of the London Act. Penalties are prescribed for (*a*) constructing or reconstructing water-closets, etc., not in accordance with this Act, or any bye-laws, or in defiance of notice or prohibition; (*b*) for discontinuing any such water supply without lawful authority; (*c*) illegally or wilfully injuring or constructing a drain or water-closet so as to create a nuisance or danger to health (sec. 41).

Water Supply.—Owing to the privileges granted, from time to time, to companies and other corporate bodies, sanitary authorities are under certain restrictions as to their supplying water. Where a water company has parliamentary powers to supply water over any given area, the S.A. must give notice to the company stating the purposes for which and extent to which it requires water; and if the company are able and willing to supply sufficient and proper water for the purposes of the local authority, this latter body may not construct any water-works within that area (P.H.A., 1875, sec. 52). Moreover, sec. 332 of the Act provides that when the supply of water must be taken from a running stream, the S.A. before abstracting water from such stream, river, or source, must obtain the consent in writing of any person or persons who have prior claims upon those streams or sources.

When not hampered by either of the foregoing restrictions, any S.A. may construct works for supplying any part of their district with water, or may take on lease, hire, or purchase works (with the sanction of the M.H.), or contract for the supply (P.H.A., 1875, sec. 51). When a S.A. supply water within their district, they have the same powers and are under the same restrictions for carrying their mains within and without their district as they have and are subject to in respect of their sewers (sec. 54). The water supplied must be pure and wholesome, and under sufficient pressure as will carry the same to the top storey of the highest dwelling-house in the district supplied. There is, however, no obligation to provide a constant supply under pressure (sec. 55). The S.A. have power to charge water-rates and rents in respect of premises to which they supply water, while all public cisterns, pumps, wells, etc., used for the gratuitous supply of water to the inhabitants of a district, vest in and are under the control of such authority (secs. 56 and 64).

The same Act (sec. 62) gives any S.A. power to require houses which are without a proper water supply to be so supplied, if it can be furnished at a cost not exceeding the water-rate authorized by any local Act or twopence per week, or such other cost as the M.H. may, upon application, determine to be reasonable. In order to guard against the pollution of sources of water supply, the S.A. have power to proceed against offenders (secs. 67 and 69). If the water of any well or cistern is deemed to be injurious to health, a justice's order may be obtained for its being permanently or temporarily closed, or the water to be used for certain purposes only, and for the payment of any necessary analysis of the sample at the cost of the S.A. (sec. 70).

The general provisions of the P.H.A., 1875, in respect of water supply may be briefly summarized by saying that it is the duty of the S.A. to provide their district with water, where danger exists to the health of the inhabitants from either the unwholesomeness or the insufficiency of the existing supply, and a proper supply can be got at reasonable cost. If the S.A. neglect to do this duty, the same proceedings can be taken to make them perform it under sec. 299 of the Act of 1875, or, if they are a rural sanitary authority, under the L.G A., 1894, secs. 16 and 19, just as can be taken in the case of their failing to supply the district with sewers. But cases arise where it is impossible for the S.A. to supply water at a reasonable cost; under these circumstances they may require the owner to do so, if he can at reasonable cost (P.H. (Water) A., 1878, sec. 3). If neither the S.A. nor the owner can provide water at a reasonable cost, then, if the absence of a proper water supply creates a nuisance that the

house is unfit for habitation, steps may be taken to obtain a justice's order prohibiting its being so used for human habitation (P.H.A., 1875, sec. 97).

It was largely to meet difficulties of this kind, especially in rural districts, that the P.H. (Water) A. of 1878 was designed. It applies to every rural sanitary authority, and also to such urban authorities as the M.H. may order (sec. 11). Under sec. 3 of this same Act, it is the duty of the local authority to provide or require the provision of sufficient water supply to every occupied dwelling-house within their district. From time to time they may take steps, by means of inspections on the part of their officers, to see that these conditions are fulfilled. The same powers of entry upon premises are given as are conferred by secs. 102 and 103, P.H.A., 1875, in respect of nuisances (sec. 7); and if the M.O.H. reports that an occupied house is without a proper water supply, and the S.A. are of opinion that such a supply can be provided at a reasonable cost (the interest on which at 5 per cent. shall not exceed twopence a week, or as the M.H. may, on the application of the S.A., decide to be reasonable in the circumstances), the S.A. may require the owner, subject to appeal to the M.H., to provide such supply within a specified time, and in case of default may themselves carry out the necessary works at his expense. The authority may, on cause being shown why the requirements of the notice served by them should not be complied with, withdraw the notice or modify the terms thereof. Nothing, however, in this Water Act must be deemed to relieve the S.A. from the duty imposed upon them by the P.H.A., 1875, of providing their district or any contributory part of it with a supply of water, where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply, and a general scheme of supply is required, and can be got at a reasonable cost (secs. 3 and 4).

In order to prevent houses being built in situations where they cannot be provided with water, the Water Act, 1878, has prohibited (sec. 6) the owner of any dwelling in a rural district that may be erected or rebuilt from the ground floor after July 4, 1878, from permitting such house to be occupied without a certificate from the S.A. that it is provided with a sufficient and available supply of wholesome water; such certificate to be based upon the report of the M.O.H. or sanitary inspector. Sec. 9 of the same Act provides that if the S.A. furnish a stand-pipe for water supply, they may make water-charges upon every dwelling within 200 feet, just as if the supply were actually given on the premises; but they may not make this levy upon houses which

have a good supply within reasonable distance, from another source, unless the water from the stand-pipe is used by the inmates.

The L.G.A., 1894, sec. 8 (1) (*e*), empowers a parish council to utilize any well, spring, or stream within the parish, and to provide facilities for obtaining water therefrom, consistent with the just rights of any person or corporation; but these powers do not in any way derogate from the obligations of a rural sanitary authority in respect of supplying water.

Under the Rivers Pollution Prevention Act, 1876, proceedings may be instituted, in respect of pollution of streams by sewage or solid matters, by any private person or aggrieved local authority (sec. 8); but in respect of manufacturing or mining effluents, a S.A. only can take action, and that subject to the approval of the M.H. The Ministry, in giving or withholding consent, must have regard to the industrial interests involved, and the circumstances and requirements of the locality. They shall not give their consent to proceedings by a S.A. of a district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the effluents from such manufacturing processes are reasonably practical and available, and that no material injury to the interests of such industry will be caused by the proceedings (sec. 6). These powers are capable of further amplification by the formation of River Boards, composed of joint Committees of County Councils, for the purpose of better enforcement of the R.P.P.A. Sec. 14 of the L.G.A., 1888, confers upon County Councils the powers of S.A. under the R.P.P.A., and enables the M.H. to form joint Committees of administrative Counties through which a river or part of a river passes. Such a joint Committee has all or any of the powers of a S.A. under the Act.

The water supply of the Metropolis is now in the hands of the Metropolitan Water Board. This Board controls the water supply not only in London, but also over a large extra-metropolitan area. Practically the Board has the same position as the provincial water companies, and so far as this question is concerned neither the county council nor any other local authority in London has any direct power. The controlling authority, as affecting the public health, over the water board is the M.H., who have the water supplied examined periodically, approve or disapprove of new sources of supply, of various regulations made by the board for preventing waste, misuse, or contamination, and who also inquire into complaints made to them as to the quality or quantity of the water supplied for domestic use.

The Metropolis Water Act gives the County Council power to ask for the repeal or alteration of any of the regulations for

the above purposes, and if the board refuse to do so, to appeal to the M.H., who, on inquiry and report of some impartial engineer or person of engineering knowledge, may make such repeal or alterations as they think fit. The same Act contains similar provisions as to the county council asking for a constant supply in any given district. The board cannot, however, be compelled to give a constant supply to any premises in any district until its regulations, as approved by the M.H., are in operation in the district, nor if the board can show that at any time after two months from the date of the service of any requisition for a constant supply more than one-fifth of the premises in the district are not supplied with the prescribed fittings. The county council have power to supply the prescribed fittings on default of owner or occupier. The M.H. have power to order a constant supply without application from the county council where they think that by reason of the insufficiency of the existing supply in the district, or the unwholesomeness of such water in consequence of its being improperly stored, the health of the inhabitants is, or is likely to be, prejudicially affected.

So far as relates to the powers of the metropolitan boroughs and borough councils in connection with the water supply, the P.H. (Lond.) A., 1891, indicates the absence of a proper water supply or of proper fittings in a house, to render such house unfit for habitation. A new house must not be occupied until the S.A. grant a certificate that it has a proper water supply (sec. 48). The water board cutting off the supply of water to any house, must give immediate notice to the S.A. (sec. 49). For the closure of polluted wells, etc., the S.A. have only to satisfy a justice that the water is "so polluted or likely to be so polluted, as to be injurious or dangerous to health" (sec. 54). It must be noted that this section gives a S.A. somewhat greater powers than sec. 70, P.H.A., 1875, inasmuch as it says not only when the water is so polluted as to be injurious to health, but when it is so polluted *or likely to be so polluted* as to be injurious *or dangerous* to health. Moreover, it gives the court no power to allow the water to be used for certain purposes only, and imposes a fine not exceeding £20 for disobedience to any order under this section.

Every S.A. under the London Act of 1891 must make bye-laws for cleansing tanks, cisterns, and other receptacles for storing water likely to be used for drinking or domestic purposes, and guarding them from pollution (sec. 50). The model bye-laws framed in connection with this section, demand: (1) the emptying and cleansing of cisterns and tanks once at least in every six months, and at such other times as may be necessary to keep them clean; (2) every such tank, cistern, or receptacle to be

fitted with a proper cover, and to be kept at all times properly covered. In cases where two or more tenants of a premises are entitled to the common use of any tank, cistern, or receptacle to which this bye-law applies, the foregoing requirements apply to the owner instead of to the occupier of the premises.

Nuisances.—In a legal sense, nuisances are of two chief kinds, namely, (1) nuisances at common law, (2) nuisances under the Public Health Acts, commonly called "statutory nuisances."

Statutory nuisances have been well defined by Wynter-Blyth as being "something which either actually injures, or is likely to injure health, and admits of a remedy, either by the individual whose act or omission causes the nuisance, or by the local authority." In the Public Health Act sense, as now understood and interpreted, the idea of a nuisance embraces future as well as present consequences. The sanitary law in respect of nuisances may be summarized in the following manner.

The provisions of the P.H.A., 1875, secs. 91 to 111, dealing with nuisances, apply to every urban and rural sanitary district, and are "deemed to be in addition to, and not to abridge any right, remedy, or proceeding under any other provisions of the Act, or under any other Act, or at law or in equity." But no person may be punished for the same offence both under these provisions and under any other law or enactment. Under this 1875 Act "nuisance" is regarded as likely to arise in connection with: (*a*) sewers, secs. 18, 19; (*b*) sewage, sec. 27; (*c*) construction of drains, closets, ash-pits, and cesspools, secs. 40, 41; by the P.H.A. (Amend.) A., 1907, nuisances under this head embrace cisterns, gutters, drains, shorts, stack pipes, and deposits of material in or on any building or land which shall cause damp in any such building; (*d*) in connection with snow, dust, ashes, filth, and rubbish, sec. 44; (*e*) swine, pigsties, and stagnant water in cellars, or the overflowing of privies and cesspools, sec. 47; (*f*) offensive trades, secs. 112, 113, and 114.

In regard to some of these cases, remedies are given by other provisions of the Act, more particularly by secs. 41, 49, and 50. It will rest with a S.A. to determine under which provisions they will proceed. The main section dealing with nuisances is, however, sec. 91, which defines the following to be nuisances to be dealt with summarily under the Act: (1) Any premises, including buildings and lands, in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, watercourse, privy, urinal, cesspool, drain, or ash-pit, so foul, or in such a state as to be a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or deposit which is a nuisance or injurious to health.

(5) Any house, or part of a house, so overcrowded as to be dangerous or injurious to health of the inmates, whether or not members of the same family. (6) Any factory, workshop, or work-place, not kept in a cleanly state, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours, dust, or other impurities generated in the course of the work carried on therein that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein. (7) Any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever; and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.

In defining these nuisances, the same section, however, provides that there is no penalty if the accumulation or deposit mentioned in (4) is necessary for, and has not been kept longer than is necessary for the carrying on of any business or manufacture, and if the best available means have been taken for preventing injury to the public health. The provisions of sub-section (6) apply to all buildings, including schools, factories, and workshops, except such as are subject to the special provisions, relating to cleanliness, ventilation, or overcrowding, of the Factories and Workshops Acts. In respect of (7), there is no penalty if the Court is satisfied that the fireplace or furnace is constructed in such manner as to consume, as far as practicable, having regard to the nature of the manufacture or trade, all smoke arising therefrom, and that such fireplace or furnace has been carefully attended by the person in charge thereof. Under the smoke sections, it is not necessary in taking action to prove anything with regard to health, it being sufficient to prove that on such and such a day and hour the chimney emitted *black* smoke. Urban sanitary authorities have some other powers with regard to smoke under sec. 171 of this Act, and under the Railway Regulation Act, 1868, and the Highways and Locomotives Act of 1878.

For interpreting the term "overcrowded" in sec. 91 (5), P.H.A., 1875, a sanitary officer usually takes as his guide the minimum standards laid down by the model bye-laws, namely, 400 cubic feet for rooms in which persons both live and sleep, and 300 cubic feet for rooms used solely for the waking life of the tenants. For factories and workshops, by the F.W.A., 1895 and 1901, overcrowding is deemed to exist when the cubic space for adults is less than 250 cubic feet, and 400 cubic feet during over-time. In the event of a second conviction for overcrowding

within three months, the Court may order the closing of the premises (P.H.A., 1875, sec. 109). Another point to be noted in connection with sec. 91 (5) of the 1875 Act, is that the words "tent, van, shed, or similar structure" may be included within it by sec. 9 of the Housing of the Working Classes Act, 1885.

Unfenced quarries and abandoned coal-mines are deemed to be nuisances under sec. 91, P.H.A., 1875, by the Quarry Fencing Act, 1887, and by the Coal Mines Regulation Act, 1887.

It is the duty of every S.A. to cause their district to be inspected for the detection of nuisances, and to enforce the provisions of the P.H.A., 1875, in order to abate the same (sec. 92), but the authority may be put in motion by any aggrieved person, or by any two inhabitants of such district, or by any officer of the S.A., or by the relieving officer, or by any police officer (sec. 93). If satisfied of the existence of a nuisance, the S.A. is required by the Act to serve a notice on the person responsible, or, if he cannot be found, on the owner or occupier of the premises on which the nuisance arises, requiring him to abate the same within a time to be specified in the notice, and to execute such works as are specified in the notice to be necessary. When the nuisance arises from the want or defective construction of any structural convenience, or where there is no occupier, the notice must be served on the owner. If the person causing the nuisance cannot be found, and the owner or occupier is not responsible for its occurrence, the S.A. may themselves abate the same without further order (sec. 94). On non-compliance with the notice, or if the nuisance, although abated, is likely to recur, the S.A. may apply to a justice, who must thereupon summon the person responsible to appear before a court of summary jurisdiction (sec. 95). If the Court is satisfied that the alleged nuisance exists, or that although abated, it is likely to recur on the same premises, it must make an order requiring him to comply with the notice, or prohibiting the recurrence of the nuisance, and directing the execution of any necessary works. The Court may further impose a penalty not exceeding £5 (sec. 96). Where the nuisance is such as to render the house unfit for habitation, the Court may order the house to be closed, and may cancel this by a further order when satisfied that the house has been made fit for habitation (sec. 97). Any person not obeying the order of the Court, or failing to use diligence, is liable to a penalty not exceeding ten shillings per day during his default, and the S.A. may carry out the order and charge him with the expenses (sec. 98). Where the person responsible for the nuisance cannot be found, the order of the Court may be carried out by the S.A.; and any matter or thing removed by the

authority in abating any nuisance may be sold (secs. 100, 101). Where any nuisance under the Act is caused by the acts or defaults of two or more persons, the S.A. may institute proceedings against any one or more of such persons (sec. 255). Where a nuisance within a district is caused by some act or default beyond its limits, the S.A. may institute proceedings provided that they be taken before a court having jurisdiction in the district where the act or default is alleged to be committed or take place (sec. 108).

For the purpose of the provisions of this Act of 1875, relating not only to nuisances, but also for infectious diseases and hospitals, any ship or vessel lying in any water within the district of a sanitary authority is subject to their jurisdiction, as if it were a house. If in any other water, it is deemed to be within such district as the M.H. may prescribe, and in the absence of any such prescription, then within the nearest sanitary district (sec. 110). The master or other officer in charge of any such ship will be deemed to be the occupier; but these provisions do not apply to any of His Majesty's ships, or to those of any foreign government.

The S.A. and their officers have rights of entry between 9 a.m. and 6 p.m. upon private premises, and in the case of a nuisance arising in respect of any business, at any hour when such business is in progress. If admission is refused, a justice's order may be obtained (secs. 102, 103).

Where sanitary authorities fail to take proceedings for abatement of nuisances, individuals may obtain a remedy in one of three ways, either (1) by complaining to the M.H., who may issue an order, enforceable by mandamus in a High Court (sec. 299); or (2) on it being proved to the satisfaction of the M.H. that a S.A. has made default in relation to nuisances under the P.H.A., 1875, the Ministry may authorize any police officer, acting within the district of the defaulting authority, to institute proceedings, which the defaulting authority might institute with regard to such nuisance (sec. 106); or (3) an individual may complain direct to a justice as to the existence of a nuisance, and the Court may make orders, penalties for disobedience of orders, etc., as in the case of a complaint relating to a nuisance made to a justice by a S.A. (sec. 105). This latter mode of procedure is obviously the most expeditious for any individual to take where he feels aggrieved by the neglect of a S.A. to take proceedings, and where the existence of a nuisance within the meaning of the Act is clear.

Under the P.H. (Lond.) A., 1891, and the L.G.A., 1899, the powers and duties of the borough councils in the capacity of sanitary authorities in London, with respect to nuisances, correspond

in the main with those already detailed as applicable to sanitary authorities in England and Wales under the Act of 1875. The London Act embodies, however, several amendments and extensions of the law which have materially strengthened the hands of the Metropolitan sanitary authorities for dealing with nuisances. Sec. 2 of the London Act extends the definition of "nuisance," making it include not only that which is *injurious* to health, but also that which is *dangerous* to health. It also makes it include any cistern, water-closet, earth-closet, or dung-pit, so foul or in such a state as to be a nuisance or injurious, or dangerous to health, and any such absence from premises of water fittings as is a nuisance by virtue of sec. 3 of the Metropolitan Water Act, 1871. Further, *any person* may give information to the S.A. of a nuisance, and it is the *duty* of every officer of the authority and of the relieving officer so to do, and to give written notice to the persons who may be required to abate it.

In giving notice requiring abatement of a nuisance, it is optional to specify the works to be executed; also, where the person responsible for causing the nuisance cannot be found, the S.A. may not only themselves abate the nuisance, but also do what is necessary to prevent its recurrence. In cases of overcrowding, the S.A. must take proceedings to abate the nuisance. The penalty for wilful nuisance or non-abatement is a fine of £10 for each offence, whether an order to abate it or prohibiting its recurrence is made or not (P.H. (Lond.) A., 1891, sec. 4).

Similarly, the maximum fines for failing to comply with an order for the abatement of a nuisance, or for acting contrary to a prohibition order, are increased from the amounts fixed by the P.H.A., 1875, to 20*s.* a day, and 40*s.* a day respectively, during default or contrary action, as the case may be (sec. 5 (9)). Wilful damage to drains, water-closets, etc., so as to create nuisances, involve a fine not exceeding £5 (sec. 15). Groundless appeals to quarter sessions against nuisance orders are checked by daily fines of 20*s.* (sec. 6 (3) (4)).

The S.A., moreover, is required by sec. 16 of the London Act to make bye-laws for the prevention of nuisances arising from (1) any snow, ice, salt, dust, ashes, rubbish, offal, carrion, fish, filth, or other matter in the street; (2) from any offensive matter running out of any manufactory, brewery, slaughter-house, knacker's yard, butcher's or fishmonger's shop, or dunghill, into any uncovered place, whether or not surrounded by a wall or fence; (3) from keeping of animals; (4) as to the paving of yards and open spaces in connection with dwelling-houses. It is, moreover, the duty of the S.A. to enforce any bye-laws made, in respect of these matters, by the county council.

Under the L.G.A. (Lond.), 1899, it is the duty of each borough council to enforce within their borough the bye-laws and regulations for the time being in force with respect to dairies and milk, and with respect to slaughter-houses, knackers' yards, and offensive businesses, and for the purpose of performing this duty, the borough council shall in all cases have the same powers of entry as was accorded under the P.H.A. (Lond.), 1891.

As regards the prevention of smoke in London, sec. 24, P.H. (Lond.) A., 1891, corresponds closely with sec. 91 of the 1875 Act; but the main provisions against nuisances arising from smoke in the Metropolis are contained in sec. 23 of the London Act, which provides that "every furnace employed in the working of engines by steam, and every furnace employed in any public bath or wash-house, or in any mill, factory, printing-house, dye-house, iron-foundry, glass-house, distillery, brew-house, sugar-refinery, bake-house, gasworks, waterworks, or other building used for the purpose of trade or manufacture (although a steam-engine be not used or employed therein), shall be constructed so as to consume and burn the smoke arising from such furnace." Sanitary authorities must carry out these provisions of this section, and, moreover, any information under it is not to be laid except under the direction of a S.A. This section extends to the port of London, where it must be enforced by the port sanitary authority, which is the City Corporation.

Unsound Food.—Under the P.H.A., 1875, the M.O.H. and inspector of nuisances have power, at all reasonable times, including Sundays, to examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk exposed for sale, or deposited for the purposes of sale, or of preparation for sale, and intended for the food of man; and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate (sec. 116), who may order it to be destroyed or so disposed of as to prevent it from being exposed for sale, or used for the food of man, and inflict a penalty not exceeding £20, or a term of imprisonment of not more than three months (sec. 117). The proof that it was not intended for the food of man rests with the person charged. Any person hindering these officers from inspecting meat, etc., is subject to a penalty of £5 (sec. 118). On complaint made by oath by any officer of a S.A. that there is reason to believe that there is kept or concealed on any premises any articles to which these sections apply, a justice may grant a search-warrant, and any person hindering the execution of this warrant is liable to a penalty of £20 (sec. 119).

Under sec. 4, S.F.D.A., 1899, the Board of Agriculture has the power to fix the limit of deficiency from the normal in the com-

position of milk, cream, butter, and cheese, and declare what addition of extraneous matter thereto, or proportion of water therein (including, as to the former, condensed milk), shall raise a presumption that the article in question is not genuine, or is injurious to health. Statutory orders under this section have been issued, and have now the force of law.

By the Butter and Margarine Act, 1907, all butter and margarine factories must be registered. It is an offence for any substance for the adulteration of butter to be found in any butter factory. Further, no butter or margarine may contain more than 16 per cent. of water, nor milk-blended butter more than 24 per cent. of water. In the marking of wrappers, all margarine must be described either as margarine or by a name embracing the word "margarine"; margarine means any article of food, whether mixed with butter fat or not, which resembles butter and is not milk-blended butter. It includes also "margarine-cheese." Milk-blended butter must be sold under such name as may be approved by the B.A., and the wrapper must set out the percentage of water contained therein and approved by the Board. The brand or mark "margarine" or "margarine-cheese" must be on the package itself and not solely on a label or ticket. The letters must be half an inch long, legible, and with no other printed matter.

Proceedings for offences under the various Acts will have to be taken in all cases within twenty-eight days from the date of purchase; the summons is to state the nature of the offence with which the defendant is charged, and to be accompanied by a copy of the analyst's certificate, and is not returnable for hearing until after the expiration of fourteen days from the date of service (sec. 19).

In markets and fairs under the control of a S.A., the sale of unwholesome meat or provisions is subject to similar provisions under sec. 15 of the Markets and Fairs Clauses Act, 1847, which is incorporated with the P.H.A., 1875. Where the market or fair does not belong to the local authority, the above provisions will not apply, unless a local Act is in force, with which the Market and Fairs Clauses Act is incorporated. A S.A. can make bye-laws for preventing the sale of unwholesome provisions in a market or fair by sec. 42 of the Act of 1847, also incorporated in the P.H.A., 1875, but owing to the stringency of secs. 116 to 119 of this latter Act, these bye-laws will be rarely necessary.

The P.H. (Food Regulations) A., 1907, enables a S.A. to make regulations for the prevention of danger arising to public health from the importation, preparation, storage, and distribution of food, in amplification of the power which such authority possesses under the P.H.A., 1875. For the purposes of these

regulations, articles commonly used for food or drink by man shall be deemed to be intended for sale for human consumption, unless the contrary be proved.

Two sets of Regulations have been issued under this Act, one the "Unsound Food Regulations" of 1908, and the other the "Foreign Meat Regulations" of 1908. Under these regulations powers are conferred on the M.O.H. or other authorized officer of a S.A. to examine and seize any article of food which in his opinion is unsound or unwholesome, in order that an application be made to a justice for an order of condemnation. Similar powers of inspection and seizure are given as to imported foreign meat. An M.O.H. may pass the meat without further examination, if provided with an official certificate of soundness affixed in the country of exportation. Foreign meat is graded into three classes. Class I. comprises scrap meat, tripe, tongue or kidney with antiseptics, and parts of uncured pig. Class II. is the carcass of the pig *uncured* minus the head and lymphatic glands. Class III. embraces severed *uncured* parts of the carcass of the pig. "Unclassed" embraces all other foreign meat.

In the Metropolis, under sec. 47, P.H. (Lond.) A., 1891, the provisions as to the sale of unsound food are somewhat more stringent. The London Act not only closely follows the lines of sec. 28, Part III., P.H. (Amend.) A., 1890, but renders the offender liable, on conviction, to a fine not exceeding £50, or imprisonment for six months with or without hard labour. The section further enforces the liability of the previous vendor of the food, and also renders any one obstructing an officer acting under a warrant for entry within twelve months after a previous conviction for obstruction and evidently with intent to prevent detection, liable to imprisonment for a month in lieu of fine. The S.A. have further the duty placed upon them of removing unsound food, as if it were trade refuse, on the receipt of written notice from a person having possession of the same.

Horseflesh.—The provisions controlling the sale of horseflesh for human food are the same in all parts of the United Kingdom. They are contained in the Sale of Horseflesh, etc., Regulation Act, 1889, which defines "horseflesh" to be horseflesh, cooked or uncooked, alone or mixed with other substances, and includes the flesh of asses and mules.

This Act provides that the flesh of horses, asses, or mules must not be sold or kept for sale for human food, except in a shop or stall over or upon which is placed in conspicuous and legible characters 4 inches long, an announcement that horseflesh is sold there. If otherwise, the M.O.H. or inspector of nuisances, or any other officer of the S.A., may seize the meat and carry it

before a magistrate, who may order as to its disposal as he thinks fit; and the offender is liable to penalty. It is illegal to supply horseflesh for human food to a purchaser asking for other meat, or for a compound article not usually made of horseflesh.

Bakehouses.—Under the Factory and Workshop Act, 1901, considerable powers of sanitary control are given to district councils over bakehouses. Sec. 97 prescribes the sanitary regulations for bakehouses; sec. 98 imposes a penalty for a bakehouse being unfit for the purpose on sanitary grounds; secs. 99 and 100 provide for the periodical limewashing, painting, etc., of these places, and require proper regulation of sleeping accommodation near bakehouses; sec. 101 prohibits underground bakehouses except where they were so used at the passing of the Act, and subject to the foregoing provision, after the first day of January, 1904, no underground bakehouse shall be used unless certified by the district council to be suitable as regards construction, light, ventilation, and in all other respects. No sleeping place is allowed on same level as a bakehouse unless there be complete separation and the sleeping room has an external window of 9 square feet, one half opening. No closet or ashpit is allowed within or to communicate directly with a bakehouse; neither may there be a drain or pipe carrying fæcal or sewage matter with an opening within a bakehouse. Each bakehouse must have a separate water cistern. An underground bakehouse means a baking room so situate that the surface of the floor is more than 3 feet below the surface of the footway or nearest ground. Sec. 102 imposes on the district council the duty of enforcing these provisions as to bakehouses.

Shellfish.—The P.H. (Shellfish) Regulations, 1915, issued under the P.H. (Reg. as to Food) Act, 1907, provides machinery for closing of shellfish layings, suspected or known to be in polluted waters, where the evidence justifies such action by an Order of the local S.A. The local authority of a district in which the layings are situate must take action on representation from another local authority in whose district the shellfish are consumed. The closing of such shellfish layings is subject to appeal to the Ministry of Health by either or all parties interested.

Milk Supplies.—It has already been shown that, under sec. 117, P.H.A., 1875, and under sec. 15, Market and Fairs Clauses Act, 1847, unwholesome provisions, including milk, may be dealt with by seizure and condemnation. The Acts, however, which are most active in regulating the milk supply, are the C.D. (Animals) A., 1878 and 1886. Under these Acts the M.H. have power to make general or special orders for (1) the registration with the local authority of all persons carrying on the trade of

cowkeepers, dairymen, or purveyors of milk; (2) for the inspection of cattle in dairies, and the general sanitation of dairies and cowsheds; (3) for securing the cleanliness of milk-stores, shops, and vessels for containing milk; (4) for guarding milk against infection; (5) and for authorizing local authorities to make regulations for any or all of the aforesaid purposes.

Under the powers thus conferred, were issued the Dairies, Cowsheds, and Milk-shops Order of 1885, 1886, and 1899, the chief effect of which Orders is to throw upon every S.A. the duty of supervising the milk trade in their district, and of carrying out certain general regulations prescribed by the Orders. These duties are common to all districts, but any S.A. may arm itself with further powers by making regulations under sec. 13 of the Order of 1885, having the force of bye-laws. The chief provisions of the Order of 1885, as amended by that of 1886, are summarized as follows:—

Section 6. (1) It shall not be lawful for any person to carry on in the district of any local authority the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as such in accordance with this article. (2) Every S.A. shall keep a register of such persons, and shall from time to time revise and correct the register. (3) The S.A. shall register every such person, but the fact of such registration shall not be deemed to authorize such person to occupy as a dairy or cowshed any particular building, or in any way preclude any proceedings being taken against him. (4) The S.A. shall from time to time give public notice of registration being required, and of the mode of registration. (5) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese, or both, and who is not also a purveyor of milk, need not be registered. (6) A person who sells milk of his own cows in small quantities to his workmen or neighbours for their accommodation need not, by reason thereof, be registered.

Section 7. (1) It shall not be lawful to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order until provision is made, to the reasonable satisfaction of the S.A., for the lighting and ventilation, including air-space (800 cubic feet per head are suggested as a minimum), and the cleansing, drainage, and water supply; (2) or without giving one month's notice in writing to the sanitary authority.

Section 8. It shall not be lawful for any . . . cowkeeper or dairyman to occupy as a dairy or cowshed any building, the lighting

and ventilation, including air-space, and the cleansing, drainage, and water supply thereof, are not such as are necessary or proper for the health and good condition of the cattle therein; and for the cleanliness of milk vessels used therein for containing milk for sale; and for the protection of the milk therein against infection or contamination.

Section 9. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk or occupier of a milk shop (*a*) to allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade . . . so far as regards the production, distribution, or storage of milk; or (*b*) if himself so suffering, or having recently been in contact as aforesaid, to milk cows or handle vessels containing milk for sale, or in any way to take part in the conduct of the trade as far as regards the production, storage, and distribution of milk; until in each case, all danger therefrom of the communication of infection to the milk, or of its contamination has ceased.

Section 10. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk, or occupier of a milk-shop or milk-store, after the receipt of notice of not less than one month from the local authority calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or room used as a milk-store or milk-shop.

Section 11. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk, or occupier of a milk-shop or milk-store, to use a milk-shop or store in his occupation, or permit the same to be used, as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk-store or shop, and of the milk vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any cowkeeper, dairyman, or purveyor of milk to keep any swine in any building used by him for keeping cows, or in any milk-store or other place used by him for keeping milk for sale.

Section 13. Any S.A. may from time to time make regulations for the following purposes, or any of them:—(*a*) For the inspection of cattle in dairies; (*b*) for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water-supply of dairies and cowsheds; (*c*) for securing the cleanliness of milk-stores, milk-shops, and milk-vessels used for containing milk for sale; (*d*) for prescribing precautions to be taken by

purveyors of milk, and persons selling milk by retail, against infection or contamination.

Section 14. The following provisions shall apply to regulations made by any S.A. under this Order :—(1) Every regulation shall be published by advertisement in a newspaper circulating in the district of the S.A. (2) The S.A. shall send to the M.H. a copy of every regulation made by them not less than one month before the date named for such regulation to come into force. (3) If at any time the M.H. are satisfied on inquiry, with respect to any regulation, that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.

Section 15. The milk of a cow suffering from *tuberculosis of the udders*, *cattle-plague*, *pleuro-pneumonia*, or *foot-and-mouth disease* (*a*) shall not be mixed with other milk ; and (*b*) shall not be sold or used for human food ; and (*c*) shall not be sold or used for food of animals, unless it has been boiled.

The Amending Order of 1886 imposed penalties of £5 for every offence, and in the case of continuing offences, an additional daily penalty of 40*s*. The courts have power to reduce these penalties if they think fit.

For the purpose of enforcing orders made under the C.D. (Animals) A., 1878–1886, the S.A. and its officers have the same right of entry as they have under P.H.A., 1875, sec. 102, in respect of nuisances.

As regards the metropolis, the P.H. (Lond.) A., 1891, which repeals, so far as they apply to London, sec. 34 of the C.D. (Animals) A., 1878, and sec. 9 of the 1886 Act, gives the same powers as are given by those sections to sanitary authorities in the provinces, to the county council and the Corporation of London to make bye-laws applicable to so much of the administrative county of London as is not included in the City, and in the City respectively. The powers of the M.H. to make regulations and orders for dairies are the same in the Metropolis as elsewhere in England and Wales. The L.C.C. under their General Powers Act, 1907, can take milk samples for examination for the presence of tubercle bacilli. If found, power is granted for examination of cows, and cause shown by the dairyman why prohibition of sale be not enforced. Every dairyman selling milk within the County of London must notify the presence of tuberculosis among his cows.

Where the P.H.A. (Amend.) A., 1907, is adopted, by sec. 52 of that Act, if an M.O.H. suspects that a milk supply is the cause of infectious disease, the S.A. can call upon the person supplying

the milk to furnish a list of places from which he derives such supply. Further, in districts in which sec. 4 of I.D.P.A., 1890, is in force, an M.O.H. can prohibit the sale of milk from suspected dairies and, if authorized by a justice having jurisdiction within the place where the dairy is situate, visit and inspect dairies without his district and, if accompanied by a veterinary officer, can inspect the animals. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk on report to his S.A. that body can give 24 hours' notice to the dairyman to appear before them and show cause why the supply of milk in their district should not be prohibited. If he fail to show cause, they may order accordingly, notifying to the S.A. and C.C. of the district in which the dairy is situate, and also to the M.H. The order must be withdrawn on the S.A. being satisfied that the milk supply has been changed, or that the cause of infection has been removed.

The foregoing legislative enactments as to the control of milk supplies are likely to be superseded by more drastic Orders issued by the M.H. under the Milk and Dairies Acts, 1915 and 1920. These Acts are not yet operative, but come into force on a date to be appointed by the M.H. The Acts repeal the C.D. (A.) A., 1878 and 1886, also sections 9 and 11 of the S.F.D.A., 1899. The provisions and scope of these new Milk and Dairies Acts of 1915 and 1920 are extensive and embrace the following features. The M.H. may make general or special Orders as they think fit relating to registration of dairies and dairymen with the S.A.; licensing of dairymen by a S.A.; the inspection of dairies, persons employed and cattle by officers of the S.A.; the lighting, ventilation, cleansing, drainage, and water supply of dairies; the cleanliness of milk stores, milk shops, and milk vessels; the protection of milk from contamination; the prevention of the sale of infected or dirty milk or milk products; the cooling, conveyance, and distribution of milk; the labelling, marking, sealing, or closing of churns and vessels; the prevention of the adulteration of milk; the conditions under which milk designated "certified milk" may be sold; the authorization of regulations by a S.A. for these purposes, subject to such conditions as the M.H. prescribes.

Any Orders issued by the Minister of Health must be concurred in by the Minister of Agriculture and Fisheries and also be laid before both Houses of Parliament.

Sec. 1 (2) authorizes the person making an inspection of cattle to require any cow to be milked from any particular teat in his presence and to take a separate sample from any teat. By secs. 2 and 3, the M.O.H. of a county or county borough,

and, by Order of the M.H., of any S.A. for an area within a county, if of opinion that *tuberculosis* is caused, or is likely to be caused, by the consumption of milk supplied by any dairy in which cows are kept within such county, county borough, or S.A. or area within a county, may put in force the procedure for stopping the supply of milk as is given in the first schedule of the Act. This procedure is identical practically with that laid down in Infectious Diseases Prevention Act, 1890. Further, if the M.O.H. of any S.A. has reason to suspect that *tuberculosis* is likely to be caused by any milk which is sold within his district, he shall endeavour to ascertain the sources of supply, and give notice of any facts ascertained to the M.O.H. of the county or county borough in which the cows from which the milk is obtained are kept. On receipt of such notice, the county or county borough M.O.H. shall cause the cattle in the dairy to be inspected. The results of such inspection, with copies of bacteriological and veterinary reports must be sent to the M.O.H. who gave notice, together with an account of any action taken (sec. 4).

By sec. 5 it is an offence under the Act to sell or offer for sale any milk from a cow which has tuberculosis, acute mastitis, suppuration of the udder, anthrax, foot and mouth disease, or actinomycosis of the udder, if it is proved that the seller knew, or by exercise of ordinary care could have ascertained, that the cow was so suffering. Sections 6 and 7 lay down that milk sold in the streets from vehicles or receptacles must be sold only from vehicles and receptacles on which the vendor's name and address are conspicuously inscribed. Receptacles for the sale of condensed, machine skimmed, or skimmed milk must be clearly so labelled. Powers as to taking of samples under the Act by officers of the S.A. are laid down in sec. 8, and sec. 9 amends the provisions of the S.F.D.A., 1875 and 1907, as to procedure in the taking of milk samples and subsequent proceedings in connection therewith. The details as to procedure are given in the section of this chapter dealing with adulteration of food. The appointment of veterinary inspectors under the Act, and Orders made under it, are provided for in sec. 10.

Sec. 12 is quite a new departure in that it enables a S.A., with the approval of the M.H., to establish and maintain milk depôts, also to purchase and sell milk at cost price within their area, make and sell milk products, distribute, store, cool, clean, and otherwise treat milk in their area. The S.A. can exercise any such powers either itself or through the agency of any organization approved by them, also with the consent of any other

S.A. it may exercise these powers in the area of such other S.A.

Sec. 13 provides that the M.H., after local inquiry, may make an order, enforceable by mandamus, compelling a defaulting local authority to perform its duties under the Act; or in the case of a district council, all its powers under the Act and Orders may be transferred to the county council. Sec. 15 allows a S.A. to delegate to a committee any of their powers or duties (other than raising rates) under the Act or Orders. At least one-third of the members of the committee shall be members of or elected by any agricultural committee appointed by a local authority having jurisdiction in their area or otherwise be representative of the interests of agriculture.

The Act applies also to London, and its powers, otherwise conferred on a S.A. with respect to the supply and distribution of milk, are exercisable by the London County Council; but if the L.C.C. fail to exercise such powers, it is lawful for a S.A. in the county to undertake the same, and the M.H., in approving any scheme submitted for the purpose, may require the possible subsequent reversion of the powers to be left open to be taken over by the L.C.C. should such be deemed advisable. The Act repeals sec. 20 of the P.H. (Lond.) A., 1891, so far as it relates to dairymen, cowhouses, and places for keeping cows, also subsection (4) of sec. 6 of London Government Act, 1899, as relating to dairies and milk, and also sec. 5 of the L.C.C. General Powers Act, 1908. These repeals only come into force from date when a milk and dairies Order providing for the licensing of dairies and dairymen comes into force.

The expression "dairy" in the Milk and Dairies Acts, 1915 and 1920, includes any farm, cowshed, milk store, milk shop, or other place from which milk is supplied on, or for sale, or in which milk is kept or used for purpose of sale or manufacture into butter, cheese, dried milk, or condensed milk for sale; and, in the case of a purveyor of milk who does not occupy any premises for the sale of milk, includes the place where he keeps the vessels used by him for the sale of milk, but does not include a shop from which milk is not supplied otherwise than in the properly closed and unopened receptacles in which it was delivered to the shop, or a shop or other place in which milk is sold for consumption on the premises only. The expression "milk" includes cream, skimmed milk, and separated milk.

Adulteration of Food.—The legislative enactments relating to this matter, in respect of the whole United Kingdom, are contained in the Sale of Food and Drugs Act, 1875, the Sale of Food

and Drugs Act Amendment Act, 1879, the Margarine Act, 1887, and Butter and Margarine Act, 1907, the Sale of Food and Drugs Act, 1899, and, so far as concerns England and Wales, also the Local Government Act, 1888. As affecting milk and milk products important provisions are contained in the Milk and Cream Regulations of 1912 and 1917, and the Milk and Dairies Act, 1915 and 1920. These latter Acts are in abeyance at present.

The S.F.D.A., 1899, defines "food" as including every article used for food or drink by man, other than drugs or water, and any article which ordinarily enters into or is used in the composition or preparation of human food, and shall also include flavouring matters and condiments; and "drug" as including medicine for external as well as internal use. The S.F.D.A., 1875 (sec. 2), enacts that "no person shall mix, colour, stain, or powder (or order or permit any other person to mix, colour, stain, or powder) any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any article so mixed, coloured, stained, or powdered . . ." (sec. 3). "No person shall, except for the purpose of compounding, . . . mix, colour, stain, or powder (or permit any other person to mix, colour, stain, or powder) any drug with any ingredient or material so as to affect injuriously the quality or potency of such drug, with intent that the same may be sold in that state; and no person shall sell any drug so mixed, coloured, stained, or powdered . . ." (sec. 4). The penalty for such injurious admixture is a fine not exceeding £50 for a first offence; subsequent offences are misdemeanours, punishable by imprisonment with hard labour for a period not exceeding six months. No liability is, however, incurred if the accused person can show that he was unaware of the admixture, and could not, with reasonable diligence, have ascertained it (sec. 5).

No person shall sell, to the prejudice of the purchaser, any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding £20; but no offence shall be deemed to be committed under this section in the following cases:—(1) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof; (2) where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent; (3) where the food or drug is compounded . . . [and the pro-

visions of the seventh and eighth sections are observed]; (4) where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation" (sec. 6). As regards these exemptions, the *onus probandi* rests with the defendant (sec. 24). No person shall sell any compound, drug, or article of food which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding £20 (sec. 7); but no offence under this section is committed in respect of the sale of a drug or article of food mixed with an ingredient not injurious to health, if it is labelled as "mixed" at the time of sale (sec. 8).

"No person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it, so as to affect injuriously its quality, substance, or nature; and no person shall sell any article so altered without making disclosure of the alteration, under a penalty not exceeding £20" (sec. 9). In any prosecution under this Act, the defendant is to be discharged if he proves to the satisfaction of the Court (*a*) that he bought the article as being the same in nature, substance, and quality with that demanded by the purchaser, and with a written warranty to that effect; (*b*) that at the time of sale he had no reason to believe it to be otherwise; and (*c*) that he sold it in the same state as when he purchased it (sec. 25).

As an outcome of the report of a committee which inquired into the uses and abuses of preservatives and colouring matters in food, it is probable that this Act will be soon amended and strengthened in special reference to these points; the recommendations made have already been given on p. 169.

In order to carry out the provisions of this Act, in every district a competent person may be, and if required by the M.H. must be, appointed as public analyst (sec. 10). In the case of boroughs having a separate Court of Quarter Sessions, or a separate police force, this appointment is made by the town council; while for all other parts of the country it is made by the county council. All these appointments and re-appointments are subject to the approval of the M.H. When a public analyst is thus appointed, any purchaser of an article of food or drug within the district shall be entitled to have it analysed for a fee of 10*s*. 6*d*., otherwise by another analyst, at such fee as he may require, and in either case to have a certificate of the result (sec. 12). The M.O.H., the sanitary inspector, or any other officer charged by the S.A. with the execution of the Act, may procure samples of food and drugs, and submit them to the public analyst (sec. 13). The quantities of the samples purchased under sec. 13 should not be less, in the case of milk, than 1 pint; butter, $\frac{3}{4}$ of a lb.; lard,

$\frac{3}{4}$ of a lb.; coffee, $\frac{3}{4}$ ot a lb.; spirits, $\frac{3}{4}$ of a pint. Any person purchasing an article for analysis shall, upon the completion of the purchase, forthwith notify to the seller his intention to have it analyzed by the public analyst; and shall offer to divide it into three parts, to be then and there separated, and each part to be marked and sealed or fastened up, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller. He must retain one of the three parts for future comparison, and deliver the third to the public analyst.

Samples may be sent to the analyst by post, in a registered letter, if his residence is two miles from that of the purchaser (sec. 16). Any person refusing to sell to an officer of the S.A. any article of food or drug on sale by retail, the price being tendered, and the quantity demanded not being greater than is reasonably requisite, is liable to a penalty not exceeding £10 (sec. 17). The certificate of the analyst must be in a prescribed form (sec. 18), and is sufficient evidence of the facts therein stated, unless the defendant requires the analyst to be called as a witness (sec. 21). The B.A. have the power to fix the limits of deficiency from the normal in the composition of milk, cream, butter, etc. The justices before whom a case is heard may, at the request of either party, cause any article of food or drug to be sent to the Commissioners of Inland Revenue for analysis by the chemists of their department at Somerset House (sec. 22).

Owing to certain defects in the Act of 1875, an Amendment Act was passed in 1879. This latter Act qualifies the earlier one by stating that "it shall be no defence to allege that the purchaser is not prejudiced by the sale of adulterated articles, on the ground that he bought it for analysis only; or to allege that the article in question, though defective in nature, *or* substance, *or* quality, was not defective in all three respects" (sec. 2). "The M.O.H., inspector, or cons able charged with the execution of the Act, may procure, at the place of delivery, a sample of milk in course of delivery to the purchaser or consignee, in pursuance of any contract; and may submit the sample to the public analyst" (sec. 3). "The seller, or his representative, if he refuses to allow a sufficient sample to be taken, is liable to a penalty not exceeding £10" (sec. 4). "As regards spirits not adulterated otherwise than by admixture of water, it is a good defence to prove that the admixture has not reduced the spirit more than 25 degrees under proof for brandy, whisky, or rum; or 35 degrees under proof for gin" (sec. 6).

Under the Milk and Dairies Acts, 1915 and 1920, the proceedings as to taking of milk samples is somewhat different to

that given for other foods and drugs in the S.F.D.A., 1875, 1899, and 1907. The special provisions under the new Milk Act are briefly as follows. A purveyor of milk from whom a sample has been procured may be compelled to give name and address of the consignor from whom he received the milk; and the S.A. may take one or more samples in course of transit or delivery from such consignor. Within sixty hours after the sample of milk was procured from the purveyor, he may serve on the S.A. a notice stating the name and address of the consignor from whom he received the milk, and the time and place of delivery to the purveyor by the seller or consignor of milk from a corresponding milking, and requesting them to take immediate steps to procure, as soon as practicable, a sample of milk in the course of transit or delivery from the consignor, unless a sample has been so taken since the sample was procured from the purveyor, or within twenty-four hours prior to the sample being procured from the purveyor; and where a purveyor has not served such notice as aforesaid, he shall not be entitled to plead a warranty as a defence in any such proceedings; and if the S.A., after such notice, fails to procure a sample in accordance with the foregoing provisions no proceedings may be taken under the S.F.D. Acts in respect of the sample of milk procured of the purveyor. If proceedings are taken against the purveyor, a copy of the analyst's certificate of every sample taken in course of transit or delivery shall be furnished to him. The S.A. may take proceedings not only against the purveyor, but also against the consignor of milk. If a sample is taken in course of transit or delivery, the owner of the cows may, within sixty hours, serve on the S.A. a notice to take immediate steps to procure, as soon as practicable, a sample from a corresponding milking of the cows, and the foregoing provisions shall apply accordingly.

In order to prevent the fraudulent sale of margarine for butter, the Margarine Act, 1887, was passed. Sec. 3 of this Act defines "butter" as made exclusively from milk, or cream, or both, with or without salt or other preservative, and with or without added colouring matter. "Margarine" includes all substances, whether compounds or otherwise, prepared in imitation of butter, and whether mixed with butter or not. It shall be unlawful to manufacture, sell, or expose for sale, or import any margarine the fat of which contains more than 10 per cent. of butter fat (S.F.D.A., 1899, sec. 8). Every package or parcel of margarine must be so marked, in capital letters not less than three-quarters of an inch square (sec. 6). All margarine factories must be registered with the S.A., by whom the public analyst of the district is appointed (sec. 9). Officers authorized to take samples under the Sale of

Food and Drugs Act may take samples of butter (or substances purporting to be butter which are exposed for sale and not marked as margarine) without going through the form of purchase required by that Act, but otherwise complying with its provisions as to dealing with the samples (sec. 10). Any such substance not being marked as margarine is to be presumed to be exposed for sale as butter, so that there is a possible offence under both Acts. There is a saving clause similar to sec. 25 of the Sale of Food and Drugs Act, viz. that the vendor is absolved if he proves that he bought the article with a written warranty, and sold it, in the same state as when bought, believing it to be butter.

Under the S.F.D.A., 1899, any person who imports into the United Kingdom, any margarine or margarine-cheese, except in packages conspicuously marked; or adulterated or impoverished butter (other than margarine); or adulterated or impoverished milk or cream, except in packages or cans marked with a name or description indicating that the butter or milk or cream has been so treated; or condensed, separated, or skimmed milk, except in tins or other receptacles which bear a label whereon the words "Machine-skimmed Milk" or "Skimmed Milk," as the case may require, are printed in large and legible type; or any adulterated or impoverished food to which by Order in Council this section shall be applied, shall be liable, on summary conviction, for the first offence to a fine not exceeding £20, for the second offence to a fine not exceeding £50, and for any subsequent offence to a fine not exceeding £100.

The word "importer" in this Act includes any person who, whether as owner, consignor, or consignee, agent, or broker is in possession of, or in any wise entitled to the custody or control of the article. Prosecutions for offences under these sections of the Act shall be undertaken by the Commissioners of Customs, who shall take such samples as necessary; divide each sample into three parts, sending one to the importer, one to the principal chemist of the Government laboratories, and retaining one part (secs. 1 to 4). The result of the analysis in the certificate of the principal chemist shall be sufficient evidence of the facts therein stated. If an offence has been committed, the name of the importer and the destination of the consignment shall be communicated to the Board of Agriculture by the Customs. An article of food shall be deemed to be adulterated or impoverished if it has been mixed with any other substance, or any part abstracted so as to affect *injuriously* its quality, substance, or nature.

When either the M.H. or the B. of A. consider, in relation to any articles of food, that the general interests of the consumers and

agriculture respectively have been or are affected adversely they may direct one of their officers to procure for analysis samples of food as if he were an officer authorized to act under the S.F.D.A., 1875, except that the sample shall be divided into four parts, three of such parts being dealt with as under sec. 14 of the S.F.D.A., 1875, as amended by this Act of 1899, and the fourth part sent to the M.H. or B. of A. as the case may be. If any S.A. fails to enforce or execute any of the provisions of the S.F.D.A. in relation to any article of food, and such failure affects the interests of the consumers or agriculture, either the M.H. or B. of A., as the case may demand, may by Order empower one of their officers to execute and enforce these provisions and charge any expenses to the defaulting sanitary authority.

The B. of A. may make Regulations (sec. 4) as to the deficiency of normal constituents, the addition of extraneous matter and the proportion of water in respect of milk, cream, butter, and cheese. The following Regulations have been made. Sale of Milk Regulations, 1901, to the effect that milk not sold as skimmed, separated, or condensed milk, shall be presumed to be *not* genuine if it contains less than 3 per cent. of milk fat and less than 8·5 per cent. of milk solids other than milk fat. Sale of Milk Regulations, 1912, to the effect that skimmed or separated milk, not being condensed milk, shall be presumed to be *not* genuine if it contains less than 8·7 per cent. of solids not fat. An amendment Order of 1917 to these Regulations forbids more than 28 grains of boric acid to be added to the pound of preserved cream. No thickening substance may be added to cream, and no preservatives may be added to cream containing less than 35 per cent. by weight of fat. Only boric acid, borax, or peroxide of hydrogen may be added to cream containing 35 per cent. or more of fat. If so treated, such cream must be labelled as "preserved cream." The Sale of Butter Regulations, 1902, state that butter containing more than 16 per cent. of water shall be presumed to be *not* genuine.

The Margarine Act, 1907, lays down that margarine must be sold as such or by a name embracing the word "margarine." Milk-blended butter must be sold under such name as may be approved by the B. of A., and the wrapper must set out the percentage of water contained therein and approved by the Board. This Act gives powers also to B. of A., to M.H., and the S.A. over all processes of manufacture, blending, reworking, or treatment of butter and similar substances, and moreover lays down a limit of not more than 16 per cent. of moisture in butter and margarine, and not more than 24 per cent. in milk-blended butter. Such goods may not be imported. Powers are also given

to M.H. as to prohibition of the use of preservatives in butter, margarine, and milk-blended butter.

A prosecution under S.F.D.A., 1899, in respect to the sale of adulterated food, must be instituted within twenty-eight days, and a warranty or invoice is no defence unless defendant, within seven days after service of summons, sends to purchaser a copy of such warranty or invoice, and a written notice that he intends to rely on that warranty (secs. 19 and 20).

Infectious Diseases.—The P.H.A., 1875, enacts that, upon the certificate of a M.O.H. or other medical practitioner that the cleansing and disinfecting of any house or part thereof, and of any articles therein, would tend to prevent infectious disease, it is incumbent on the S.A. to serve notice upon either the owner or occupier, requiring him to cleanse and disinfect. A daily penalty not exceeding 10*s*. is incurred by default, and the authority may do what is necessary and recover the costs, or may undertake the duty in the first instance, with the consent of the occupier, at their own cost (sec. 120). Under the I.D.P.A., 1890 and 1899, the above section is repealed, and the provisions so far modified that the S.A. may, after twenty-four hours' notice, proceed to carry out such disinfection or cleansing, unless within that time the owner or occupier informs the authority that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the M.O.H. In case of default, the S.A. may cause the necessary work to be done and recover the expenses. Power of entry between 10 a.m. and 6 p.m. is given for the purposes of this section (Infectious Diseases Prevention Act, 1890, secs. 5 and 17).

By sec. 121, P.H.A, 1875, the S.A. may destroy infected bedding, clothing, or other articles, and give compensation. By sec. 6 of the Act of 1890, the authority may, by a written notice, require, under a penalty of £10, any infected clothing or other articles to be delivered to their officers for disinfection. The S.A. must take away, disinfect, and return such articles free of charge, and, in the event of any unnecessary damage, must compensate the owner.

The P.H.A., 1875, further enacts that a S.A. may provide a disinfecting apparatus and disinfect free of charge (sec. 122); also provide an ambulance and pay expenses of conveyance to hospital of infected persons (sec. 123). Where a hospital is provided within convenient distance, a justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or is lodged in a room occupied by more than one family, or is on board any ship

or vessel (sec. 124). The authority may make regulations for removing to any available hospital, and for keeping there as long as necessary, any persons brought within their district by vessel, who are infected with a dangerous infectious disorder (sec. 125). It is unlawful for any person so suffering to expose himself wilfully, without proper precautions against spreading the disorder, in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or, being in charge of any person so suffering to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which have been exposed to infection from any such disorder, but this does not apply to the transmission with proper precautions of articles for the purpose of having them disinfected (sec. 126). The owner or driver of a public conveyance so used is required under penalty to have the same immediately disinfected, but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him (sec. 127). Any person who knowingly lets for hire any house or room in which any person has suffered from such disorder, without having it and its contents disinfected to the satisfaction of a medical practitioner, as testified by a certificate signed by him, is liable to a penalty not exceeding £20 (sec. 128). Any person letting or offering for hire any house or part of a house, who on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such question, becomes liable to penalty or imprisonment (sec. 129).

The above provisions have been supplemented in districts by the I.D.P.A., 1890, by the following enactment in sec. 7 of that Act. It provides that any person who shall cease to occupy any house or room in which any person has, within six weeks, been suffering from any infectious disorder, (1) *must* have such house or room, and all articles therein liable to retain infection, disinfected to the satisfaction of a registered medical practitioner, as testified by a certificate signed by him; and (2) *must* give to the owner notice of the previous existence of such disease; and (3) *must not* knowingly make a false answer when questioned by the owner, or by any person negotiating for the hire of the house or room, as to there having, within six weeks previously, been therein any person suffering from any infectious disease. Penalties of £10 are provided in each case. Infectious rubbish must not be thrown into any receptacle for refuse without

previous disinfection; or in default a daily penalty of 40*s.* (sec. 13). In any district where these sections are in force, the S.A. must give notice of their provisions to the occupier of any house in which they are aware there is a person suffering from any infectious disease (sec. 14).

The P.H.A., 1875, secs. 131 to 133, enacts that any S.A. may build or contract for the use of hospitals for their district, two or more authorities, if necessary, combining for this purpose. The S.A. may recover from a patient, who is not a pauper, the cost of his maintenance in such hospital; and may, with the sanction of the M.H., themselves provide or contract for a temporary supply of medicine and medical assistance for the poor of their district. Further, the I.D.P.A., 1890, requires the same authorities to provide free temporary shelter with any necessary attendance, for the members of any family in which infectious disease has appeared, who have to leave their dwellings to allow of disinfection by the S.A. Any person suffering from infectious disease, and being an inmate of a hospital for infectious diseases, and who upon leaving would be without accommodation in which due precautions could be taken against the spread of infection, may, by order of a justice, be detained in hospital at the cost of the S.A. for any specified period, and such period may be extended as often as necessary (sec. 12, Act of 1890).

With a view to promote the establishment of infectious hospitals, a very important Act was passed in 1893, called the Isolation Hospitals Act, giving to county councils limited power to secure the provision of isolation hospitals in their county. It applies to England and Wales generally, but not to London, or to any county borough; other boroughs are also exempt, except by order of the M.H., if the population be less than 10,000, at the last census, or by consent of the corporation if the population be 10,000 or more. A *hospital district* under this Act may consist of one or more local areas; a "local area" being defined as including an urban or rural sanitary district, or any contributory place. This district is constituted by order of the county council. To put this Act in force, the county council may take the initiative by directing their M.O.H. to report as to the hospital requirements of any part of their county, and acting upon his report; but they may also be set in motion by a petition from any local authority, or from twenty-five ratepayers in any contributory place. The next step is for the county council to hold a local inquiry, after which they make an Order constituting the hospital district and defining its extent. No local area can be included in a hospital district without the consent of its local authority, if it has already, in the judgment of the county council,

adequate accommodation; nor must a hospital district be formed for one local area only, or for one or more local areas within the same rural sanitary district, without the consent of the S.A., unless the county council are satisfied that the S.A. are unable or unwilling to make suitable provision for the purpose. The Order constitutes a hospital committee, consisting of local representatives, but if a grant be made out of county funds, the committee may consist wholly or in part of county councillors. The Order further gives the committee power to provide and maintain a hospital; and apart from this they are authorized by this Act to make temporary arrangements for isolation, and to establish district hospitals in cottages or small buildings. They may also, subject to county council regulations, undertake the training of nurses, and may charge for their attendance outside the hospital. Every hospital is to be provided with one or more ambulances, and must, if practicable, be in connection with the system of telegraphs (sec. 13).

The county council have the power of inspecting any such hospital, and of raising money by loan for the purposes of the hospital.

"Structural" and "establishment" expenses are borne by the several local rates of the constituent local areas, in proportions to be fixed by the county council's Order. The cost of conveying, removing, feeding, medicines, disinfecting, and all other things required for patients individually, are termed "patients' expenses." For ordinary non-pauper patients they are to be paid by the local authority out of the rates of the local area from which the patient came, but the guardians are responsible if poor-law relief has been given at or within fourteen days at the time of admission. Patients desiring exceptional accommodation are themselves responsible for the cost of maintenance, "special patients' expenses," on such terms as the committee may appoint (secs. 17 to 19).

The I.H.A., 1893, has been considerably amended by the I.H.A. of 1901. Hitherto there has been some doubt as to the extent of the power of a district council or joint board who had provided a hospital under the P.H.A., 1875, to transfer their hospital to the county council. These powers have now been clearly explained, and facilities for exercising them materially furnished by the later Act. Further, difficulties in the way of hospital committees hiring temporarily a hospital from a district council whilst they themselves were erecting a permanent hospital, and also as to transferring patients from one district to the hospital of other authorities in times of stress or epidemics, are removed. The new Act, sec. 5, also provides that upon an appeal against any Order including any area in a hospital district under subsec. 3

of sec. 8 of the Act of 1893, the M.H. may confirm, disallow, or modify the Order as they think fit. Sec. 6 of the new Act now provides that the rural district council shall, to the exclusion of any other authority, be the local authority in the case where a contributory place consisting of a parish is concerned. Hitherto, under the Act of 1893, a county council could only be represented upon a hospital committee by members of their own body. This is altered by sec. 8 of the new Act, whereby the representatives of the county council upon a hospital committee may be members of the council or not.

It is, of course, of the greatest importance from a sanitary point of view that the dead bodies of persons who have died of infectious diseases should not remain unburied in such a manner as to endanger the health of the survivors. The P.H.A., 1875, sec. 142, provides that where the dead body of any one who has died of any infectious disease is retained in a room in which persons live and sleep, any justice may, on a certificate signed by a medical man, order the body to be removed by the S.A. to a mortuary, and direct the same to be buried within a time to be limited by the Order; unless the friends of the deceased undertake to so buıy the body within the time specified, it is the duty of the relieving officer to bury such body at the expense of the poor-rate; but any expenses so incurred may be recovered in a summary manner from any person legally liable to pay the expenses of the burial. A penalty of £5 attaches to any person obstructing the execution of an order made under this section

Further provisions in respect of this matter are contained in secs. 8 to 11 of the Act, the I.D.P.A., 1890, which enact that the body of a person who has died of any infectious disease must not, without a certificate from the M.O.H. or a registered medical practitioner, be retained for more than forty-eight hours elsewhere than in a mortuary, or in a room not used at the time as a dwelling-place, sleeping-place, or workroom. In such cases, and also where any corpse is retained in a building so as to endanger the health of the inmates, a justice may, upon the application of the M.O.H., order the body to be removed by the S.A. to a mortuary, and to be buried within a specified time. Unless the friends undertake to bury, and do bury within the specified time, the relieving officer must do so. The body of any person who has died from infectious disease in a hospital must not be removed except for immediate interment or to a mortuary, if the M.O.H. or other medical practitioner certify that such restriction is desirable for preventing infection. The body of any person who has died of an infectious disease must not be conveyed in any public conveyance, other than a hearse, without due

warning to the owner or driver, who must forthwith provide for disinfection.

In cases where there is any suspicion that an epidemic of infectious disease has its origin in any milk supply of the district, the powers of a S.A. under the C.D. (Animals) A., 1886, as amplified and amended under the Milk and Dairies Acts, 1915 and 1920, should not be lost sight of. They have been fully explained in the preceding section. In addition to these powers and provisions, sanitary authorities of districts have power to prohibit the supply of milk from suspected dairies (sec. 4, I.D.P.A., 1890). If the M.O.H. has reason to believe that the consumption of milk from any dairy, farm, cowshed, milk-store, milk-shop, or other place from which milk is supplied within or without his district, has caused or is likely to cause infectious disease to any person residing in the district, he may, if authorized by a justice having jurisdiction in the place where the dairy is situate, inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk, he must report to the S.A., forwarding also any report furnished to him by the veterinary surgeon. The local authority may then give not less than twenty-four hours' notice to the dairyman to appear before them, and show cause why the supply of the milk in their district should not be prohibited. If in their opinion he fails to show such cause, they may order accordingly, and must give notice of the facts to the S.A. and the county council of the district in which the dairy is situate, and also to the M.H. The order must be forthwith withdrawn on the S.A. or the M.O.H. being satisfied that the milk supply has been changed, or that the cause for infection has been removed. Penalties of £5, and if a continuing offence of 40*s*. a day, are provided for contravention of this section of the Act.

In respect of tuberculosis, considerable control and means of taking action against this disease arise out of the National Insurance Act, 1911. Although this is a public health Act, in actual practice a S.A. and its officers have comparatively little to do with its administration. The working of its provisions is centralized in the M.H., which operates mainly through Insurance Committees where such have been established. In many areas, these Insurance Committees exist distinct from the S.A. This latter body, therefore, concerns itself chiefly with those sections of the Act making special reference to the S.A. Sections 16 and 22 of the N.I.A., 1911, deal with tuberculosis and sanatorium benefits and empower councils of boroughs and districts to contribute

certain expenditure on medical and sanatorium benefit. Sec. 17 gives power to extend sanatorium benefit to dependants. The most important provisions of the Act are in secs. 59 to 62 inclusive, which give power to Insurance Committees to provide tuberculosis dispensaries, sanatoria, and hospitals for advanced cases of tuberculosis. The practice in relation to Insurance Committees varies. Where such exist they can act independently of the S.A., but in a number of places the local S.A. is the Insurance Committee, an arrangement which is convenient and works well. Sec. 63 authorizes inquiries to be held in districts in which excessive sickness occurs, due or alleged to be due to neglect on the part of the S.A.

The control of venereal disease is furnished by the P.H. (Venereal Diseases) Regulation, 1916, and the Venereal Disease Act, 1917. Venereal disease means syphilis, gonorrhœa, and soft chancre. By the Regulations, 1916, every County Council and County Borough Council in England and Wales and the Common Council of the City of London must prepare and submit to the M.H. a scheme, (*a*) for the treatment at and in hospitals or other institutions of persons suffering from venereal disease; and (*b*) for supplying medical practitioners with salvarsan or its substitutes for the treatment and prevention of venereal disease. After approval by the M.H., the council concerned must put the scheme into execution at its own cost. All information obtained in regard to any person treated under the scheme approved shall be regarded as confidential. With the approval of the M.H. any council may make arrangements to delegate its powers to the managers of a hospital, institution, or society. Any council may make provisions for the giving of instructional lectures or publication of information relating to venereal disease. Under the V.D.A., 1917, no one but a duly qualified medical practitioner may, for reward either direct or indirect, treat, prescribe for, or advise any person for venereal disease. This applies only to areas where a gratuitous scheme approved by the M.H. is in operation. No person, other than a S.A. or M.H., is allowed to treat any person with venereal disease, or advise treatment by advertisement or public notice, nor may he recommend any internal or external medicines or medicaments for the cure, relief, or prevention of venereal diseases. The penalties under this Act are severe against offenders, being imprisonment with hard labour up to two years, or a fine up to £100.

The relation of schools to infectious diseases, and the action of the S.A. in the matter, is of importance. By Article 88 of the Education Code, a S.A. has alternative power with respect to elementary public schools: (*a*) to notify the managers that par-

ticular scholars be for a specified time excluded from attendance, or (*b*) to require the school to be closed for a specified time. Managers of schools, after complying with the requirements of a S.A., have the right of appeal to the Education Department, if they consider any notice to be unreasonable. A S.A. has no power in respect to Sunday schools, or other private schools; except in so far as these may contravene sect. 91 (5) (nuisance from overcrowding), or sec. 126 (exposure of infected person or thing), or other provision of the P.H.A., 1875, but usually the managers of such schools are only too ready to co-operate in efforts for securing the public health.

Where the Public Health Acts Amendment Act, 1907, is adopted, the powers of the S.A. to deal with the infective diseases are materially strengthened. By sec. 52 of this Act, if any person knows that he is suffering from an infectious disease he shall not carry on any trade or occupation unless he can do so without risk of spreading the infectious disease. The penalty in respect of each offence is forty shillings. Further, if the M.O.H. suspects that any case of infectious disease is attributable to the milk-supply, the S.A. can call upon the dairyman supplying the milk to furnish a list of places from which he derives such supply. Payment for these lists to be at the rate of sixpence for every twenty-five names. Failure to comply entails a fine of £5 and a running penalty not exceeding £2 per day (sec. 53). Dairymen are also required to notify the medical officer of any cases of infectious disease amongst their employees (sec. 54).

Infected clothes may not be sent to a laundry, and the S.A. may, on application of any person, pay the expenses of the disinfection of any such clothing or bedding, if carried out by them or under their direction (sec. 55). Also, the authority is empowered to cleanse, purify or destroy any article in a dwelling-house which, by reason of its filthy condition, might prove dangerous to the health of any persons in the house. Reasonable compensation to owner may be given (sec. 56).

Children suffering from infectious disease may not attend school (sec. 57), and principals of schools where a scholar is suffering from an infectious disease can be called upon to furnish lists of scholars to the S.A.; the penalty in default being a fine of 40*s*. These lists to be paid for at the rate of sixpence for twenty-five names (sec. 58). The borrowing of books from public or circulating libraries is illegal for persons knowing themselves to be suffering from an infectious disease (sec. 59).

Further material powers of control over infectious diseases arise out of the provisions of the Midwives Acts, 1902 and 1918, as to the extension of diseases of this kind among lying-in women,

by the Cleansing of Persons Act, 1897, and the Children Act, 1908, especially as to the cleansing of verminous children.

Under sec. 61 of P.H. (Amend.) Act of 1907, a S.A. may exercise powers of sec. 15 of the Infectious Disease (Prevention) Act, 1890, whether that section has or has not been adopted in the district, and, if they so determine, can remove persons from infected premises and provide for their temporary shelter or accommodation. If any such person does not consent to be so removed, a compulsory order from two justices can be obtained on application by the S.A. Penalties attach to wilful disobedience or obstruction of an order under this section. Sec. 126 of the P.H.A., 1875, which imposes a penalty on the exposure of infected persons and things is amended so as to read in paragraph two as if the words "or causes or permits such sufferer to be exposed" followed after the word "sufferer" (sec. 62). Owners or drivers of public vehicles are prohibited from knowingly conveying infected persons in public vehicles, but if such incident come to their knowledge they must give notice to the S.A., who must, on request of the owner or driver of such public vehicle, disinfect the same free of charge, except in cases where the owner or driver knew that the person conveyed was suffering from infectious disease (secs. 63 and 64). Full powers to cleanse and disinfect premises are given to the S.A. on certification by their medical officer that such cleansing and disinfection is necessary to prevent or check disease. Notice to do so may be given to owner or occupier, failure to comply within twenty-four hours gives the S.A. power to enter on any premises by day and carry the disinfection out under the superintendence of the medical officer. Reasonable compensation for damage must be given (sec. 66). A S.A. may provide nursing attendance for cases of infectious disease, where removal to hospital is likely to endanger the patient's health (sec. 67). The holding of wakes over bodies of persons dying of infectious diseases is unlawful (sec. 68).

One of the most important and valuable aids to the various foregoing provisions has been the *compulsory notification of infectious diseases* under the Notification Acts of 1889 and 1899, coupled with extensions of scheduled diseases under various Public Health Regulations issued since. The diseases now scheduled as compulsorily notifiable are: small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus fever, enteric fever, continued fever, relapsing fever, puerperal fever, plague, tuberculosis in all forms, cerebro-spinal fever, acute poliomyelitis, ophthalmia neonatorum, measles and German measles, acute encephalitis lethargica, acute polio-encephalitis,

acute primary pneumonia, malaria, dysentery, and trench fever. Power is given to a S.A., with the sanction of the M.H., to adopt within its district the notification of any other infectious disease; this is occasionally done in respect of whooping cough and chicken-pox, especially during times of epidemicity. Every medical practitioner attending on, or called in to visit, the patient shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the medical officer of health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering. The penalty for default is a fine not exceeding 40*s*. Under the same penalty, the householder is compelled to notify, but in a less formal manner. Though the system of notification is "dual" under the Act, it is so only in theory; as practically the householder's share in the notification is allowed to lapse, unless there is no doctor in attendance. The Act does not apply to Government buildings, such as barracks, nor to any "hospital" in which persons suffering from infectious disease are received; it applies to "every ship, vessel, boat, tent, van, shed, or similar structure used for human habitation." The Act gives no power of compulsory removal of patients to hospital, nor even power of entry upon premises for the purpose of making inquiries.

Sec. 130, P.H.A., 1875, enables the M.H. to make regulations for the treatment of persons affected with cholera or any other infectious disease, and by the P.H. Acts, 1896 and 1904, to make regulations for preventing the spread of such diseases as well on the seas, rivers, and waters of the United Kingdom, and on the high seas within 3 miles of the coast thereof, as on land, and may declare by what S.A. such regulations shall be enforced and executed. Cholera, plague, and yellow fever regulations have been issued under these Acts.

The main principles on which regulations on this matter have proceeded are that a report with regard to infected vessels arriving from foreign ports should be made by the Officers of Customs to the Port S.A. of the place on arrival; that infected vessels should be detained temporarily, pending visitation by the M.O.H. of the place; and that, after visitation by the M.O.H. of such vessels, or of any other vessels to which suspicion of infection attaches, the measures indicated by the regulations should be taken. Such measures have included, according to circumstances, the further detention of the vessel, the removal of persons suffering or suspected to be suffering from plague, cholera, or yellow fever, the adoption of steps to free the vessel

from causes of infection, and such other action as is expedient for the purposes of tracing the further movements of persons allowed to leave the vessel. Some modifications of the regulations have now been made.

In relation to vessels arriving from foreign ports, a new classification is adopted. The term "infected ship" is limited to a ship on which there is actually on board at the time a case of cholera, yellow fever, or plague, or on which there has been a case of cholera or plague within seven days before arrival, or a case of yellow fever within eighteen days before arrival. At the same time the term "suspected ship" is used as applying to a ship on which there has been a case of cholera or plague more than seven days before the arrival of the ship, or a case of yellow fever more than eighteen days before arrival, whether the case has occurred in the port of departure or in another port in the course of the voyage, or at any time during the voyage, and on which no fresh case of cholera or plague has occurred within the seven days, or of yellow fever within the eighteen days. In this connection, it is important that the M.O.H. of a port should keep themselves informed as to the ports that may be infected, and should advise the local Officers of Customs as to the ports from which it is anticipated that ships liable to detention by those officers might come, or at which they might have called.

If a ship is certified to be "infected" the regulations (except as regards any person actually suffering from cholera, yellow fever, or plague, or from any illness which may prove to be one or other of those diseases) prohibits the landing of any person who is on board, unless he satisfies the M.O.H. as to his name, intended destination, and intended address at such place. As regards a "suspected" ship, a similar provision does not come into operation unless the M.O.H. certifies that it is desirable that the provision should take effect. In either case the permission to land is coupled with an obligation that any change of address or destination within five days after landing must be notified forthwith either to the Port Medical Officer or to the S.A. of the district in which the place of actual destination or address is situate.

Under the regulations the measures of disinfection that may be applied to an infected or a suspected ship, as apart from articles in it, are restricted to instances in which the infection is due to cholera or plague, and they are to be confined to those parts of the ship which have been used as quarters by the person so infected, or which, in the opinion of the M.O.H., are infected with either of these diseases. The disinfection or destruction of articles on board the ship is restricted to those which may be

infected with cholera or plague. Similarly, certain proceedings for dealing with bilge water, water ballast, drinking and cooking water, which under former regulations were requisite in the case of yellow fever and plague, are now made necessary only in those instances where cholera is in question.

Provisions have been made for preventing the transmission of plague by rats on board ship, and the escape from the ship to the shore of rats that may be infected with plague. These are obligatory in the case of infected ships, but in the case of a suspected ship, only where the M.O.H. requires them to be followed. Where a ship is neither infected nor suspected by reason of plague, but has come from, or has during the voyage called at, a port infected with plague, the M.O.H. by so certifying that they are necessary, the measures for destruction of rats are to be applied and the cost borne by the S.A. The enforcement of measures for effectually stopping the access of rats from the ship to the shore is left to the discretion of the M.O.H.

In view of the part now known to be taken by a certain species of mosquito in the transmission of yellow fever to man, a provision is made enabling the M.O.H. to give a certificate requiring the taking of measures intended to secure the destruction of mosquitoes and their larvæ on board ship subject to the conditions set out in that article. The S.A. are obliged to do any such work as is specified at the request of and in substitution for the master of the ship. If they think fit, they can recover the cost of the work so done, but they may not derive any profit, and the amount recoverable may not, in relation to any piece of work, exceed £20.

For the Metropolis, the legislative enactments relating to infectious diseases are practically all contained in the P.H. (Lond.) A., 1891, secs. 55 to 87, as both the I.D.N.A., 1889 and 1899, and the I.D.P.A., 1890, are embodied in the London Act of 1891. There are, however, a few modifications necessitated by the fact that the whole of the Metropolis has been formed into one asylum district, under managers known as the Metropolitan Asylums Board, who, by the Metropolitan Poor Acts of 1867, 1871, and the Diseases Prevention (Metropolis) Act, 1883, provide asylums for the insane and infirm as well as hospitals for infectious diseases.

As regards notification in London, there is an important difference of procedure as compared with England and Wales, namely, that a copy of the certificate must be sent by the M.O.H. of a sanitary authority both to the Asylums Board and to the head teacher of the school attended by the patient (if a child), or by

any child who is an inmate of the same house as the patient. Besides this, the different medical officers of health receive weekly a full and complete list from the Asylums Board of all notifications in the respective metropolitan districts.

The London County Council have power to extend the provisions of the Act as to the notification of infectious disease to diseases not specifically mentioned. The other general provisions as to disinfection, removal of infected persons or dead bodies, and burial of the infective dead, are similar to those already explained.

Power is also given to the M.H. by sec. 13 of the L.C.C. (G.P.) A., 1890, to assign to the county council any duties and powers under epidemic regulations made by them in pursuance of sec. 134, P.H.A., 1875, as they deem desirable. In extension of the same, they may substitute the London County Council for any local authority, on whose default the council have power to proceed and act under the London Public Health Act of 1891.

Canal Boats.—Under the Canal Boats Acts of 1877 and 1884, the supervision of canal boats is placed under every S.A. through whose district a canal takes its course, or which has a piece of water coming under the definition of the word canal. It is further the duty of the S.A. to report annually as to the execution of the Acts, and as to any steps taken during the year to give effect to them. In the following summary, the sections quoted are those of the 1884 Act, unless expressly stated to be otherwise.

No canal boat must be occupied as a dwelling unless it is registered under these Acts, and then only by the number of persons of the age and sex for which it is registered (sec. 1). The owner can register the boat with any registration authority having a district abutting on the canal on which such boat is accustomed or intended to ply; and the boat must be registered as belonging to some place which is within the said district (sec. 7). When the boat passes from the canal on which the district of the authority with whom it has been registered abuts, its original registry will be recognized as operative on other canals whereon it may ply. If a canal boat is used in contravention of the Acts, the master of the boat, and also the owner, if he is in fault, will be each liable to a fine not exceeding 20*s.* for each occasion on which the boat is so used. Directly a canal boat ceases to be inhabited, it is no longer subject to the Canal Boats Acts. Upon registration, two certificates must be given to the owner, identifying the owner and the boat, and stating the place to which it belongs, and the number, age, and sex of the

persons allowed to dwell in the boat. The master of the boat must carry one of these certificates (sec. 3). A boat cannot be considered to be registered unless it is marked with (*a*) the name of the place to which the boat belongs; (*b*) the number; (*c*) the word "registered." Further, a boat will not be deemed to be lettered, marked, and numbered in conformity with these requirements unless it is so lettered, marked, and numbered on both sides of it, or in some suitable position plainly visible from both sides of the boat (sec. 7). A certificate of registration will cease to be in force in the event of any structural alterations having been made in the canal boat affecting the conditions upon which it was originally registered (sec. 1).

If any person on a canal boat is suffering from an infectious disease, the S.A. of the place where the boat is shall adopt such precautions as appear necessary, upon the certificate of the M.O.H., or other legally qualified practitioner; and may remove such sick person, and exercise the other powers conferred by the P.H.A., 1875, in this respect, and may detain the boat as long as is necessary for cleansing and disinfecting (sec. 4, Act of 1877). If any person duly authorized by the S.A. has reason to suspect any contravention of the Act, or that a person on board is suffering from an infectious disease, he may enter the boat for the purpose of inspection between 6 a.m. and 9 p.m., and may require the master or whoever is in charge of the boat to afford him facilities for so doing, and to produce the certificate of registry of the boat (sec. 5, Act of 1877).

Sec. 2 of the Act of 1877 directs the M.H. to make regulations:—(i) for the registration of canal boats; (ii) for lettering, marking, and numbering such boats; (iii) for fixing the number, age, and sex of persons who may be allowed to dwell in a canal boat, having regard to the cubic space, ventilation, separation of the sexes, general healthiness, and convenience of accommodation; (iv) for promoting cleanliness and habitable condition of such boats; and (v) for preventing the spread of infectious disease by canal boats.

In pursuance of the above powers, an Order was issued in 1878, prescribing a series of regulations which are still in force. The following is a summary of their principal sanitary provisions:—

"There must be at least one dry, clean, and weather-proof cabin in good repair. An after-cabin, intended to be used as a dwelling, must contain not less than 180 cubic feet of free air space, and a fore-cabin 80 cubic feet; every such cabin must have means of ventilation besides the door, and must be so constructed as to provide adequate sleeping accommodation.

One cabin must contain a stove and chimney. The boat must be furnished with suitable storage for three gallons of water. If intended to be ordinarily used for foul cargoes, the hold must be separated from any inhabited cabin by a double bulk-head with an interspace of 4 inches, and the bulkhead next the cargo must be water-tight. Not less than 60 cubic feet of air space must be allowed for each person over twelve years of age, and not less than 40 cubic feet for each person under that age. In 'fly-boats' worked by shifts, a cabin occupied at the same time by two persons must have a capacity of 180 cubic feet. A cabin in which a married couple sleep must not be occupied at the same time by any other male above fourteen, or female above twelve years of age. Males above fourteen and females above twelve years of age must not occupy the same sleeping-cabin at the same time, but reservation is made for married couples, and also (under certain conditions) in respect of boats constructed prior to 1878. The interior of the cabin must be repainted every three years, and must be kept clean. Bilge water must be pumped out daily. The master of the boat must at once notify the occurrence of any case of infectious disease on the boat to the S.A. of the district through which the boat may be passing, and also to the S.A. of the place of destination; he must also inform the owner, who is required to notify to the S.A. of the place to which the boat belongs. If the boat is detained by the authority for purposes of disinfection, the S.A. must obtain a medical certificate that the boat has been cleansed and disinfected, and shall cause such certificate to be delivered to the master of the boat, who cannot proceed until that certificate has been obtained. The S.A. may pay a reasonable remuneration for any such certificate."

The Acts contain special provisions with respect to the education of children living in canal boats, and enable the Education Department to make regulations on this subject (secs. 6 and 12, Act of 1877). Sec. 4 of the Act of 1884 requires the M.H. to make inquiries, from time to time, by an inspector or inspectors, specially appointed for the purpose, as to the working of these Acts and Regulations, and to report annually thereon to Parliament.

Vans and Tents.—To control the sanitation of the more or less vagrant population occupying movable dwellings other than canal boats, every S.A. possesses certain powers under the P.H.A., 1875, under the unrepealed 9th and 10th secs. of the H.W.C.A., 1885, and under the P.H. (Fruit-Pickers) A., 1882.

Sec. 9 of the H.W.C.A., 1885, provides that a tent, van, shed, or similar structure, used for human habitation (exclusive of those

used by a portion of his Majesty's military or naval forces), which is in such a state as to be a nuisance or injurious to health, or which is so overcrowded as to be injurious to the health of the inmates, whether or not members of the same family, shall be deemed to be a nuisance within the meaning of sec. 91 of the P.H.A., 1875, and the provisions of that Act shall apply accordingly. By sec. 10, any S.A. may make bye-laws in regard to such habitations. Power of entry between 6 a.m. and 9 p.m. is given to any person duly authorized by the S.A. or by a Justice of the Peace, if such person has reasonable cause to suspect any contravention of the Act, or of any bye-laws made under it, or that there is in such habitation any person suffering from any dangerous infectious disease. If any such person is obstructed in the performance of his duty under the above provisions, the person obstructing him will be liable on summary conviction to a fine not exceeding 40*s*.

As regards the accommodation and lodging of hop- and fruit-pickers, every S.A. has power under sec. 314 of the P.H.A., 1875, to make bye-laws for securing the decent lodging and accommodation of persons engaged in hop-picking within the district of such authority. This power has been extended by the Fruit-Pickers' Act of 1882, so as to enable the same authorities to make bye-laws for securing decent and proper accommodation and lodging of those engaged in the picking of fruit and vegetables.

For the proper control and regulation of the tents, sheds, barns, or other places occupied as temporary dwellings by hop-pickers and others, but not of places inhabited throughout the year, the Model Bye-laws have been promulgated. Of these, the following is a brief summary :—

"(*a*) The habitations must be clean, dry, weather-proof, ventilated, and lighted. (*b*) At least 16 square feet of floor space must be allowed in them for each adult and for every two children under ten years of age. (*c*) When intended for the reception of adults of different sexes, the habitations must be so furnished or provided that every bed is properly separated from any adjoining bed by a suitable screen or partition to secure adequate privacy to the occupants. (*d*) There must be a separate cooking-place for every fifteen persons authorized to be received. (*e*) There must be a sufficient supply of good water for drinking, cooking, and washing. (*f*) There must be adequate privy accommodation for the separate use of each sex. (*g*) Every lodger or occupant shall be provided with a sufficient supply of clean dry straw, or other clean, dry, and suitable bedding, which must be changed or properly cleansed

from time to time, as occasion may require. (*h*) Every part of the interior of the premises, the cook-houses, and privies must be thoroughly cleansed immediately before any person is received to lodge therein, the internal surfaces limewashed, and all offensive accumulations cleared away; this cleansing and limewashing must be done at least annually and repeated as required from time to time during the period of occupation."

Cellar Dwellings.—Sec. 71 of P.H.A., 1875, prohibits the separate occupation as a dwelling of any cellar built or rebuilt after the passing of the Act, or which was not lawfully so let or occupied at the time the Act was passed. Any one passing the night in a cellar is deemed to occupy it (sec. 74).

Cellar dwellings, the letting or occupation of which are not forbidden under sec. 71, are prohibited by sec. 72 from being let or occupied unless they comply with the following requirements:—(*a*) The height must in every part be at least 7 feet, 3 feet of which must be above the level of the adjoining street. (*b*) An open area at least 2½ feet wide in every part, and 6 inches below the level of the floor, must extend along the whole frontage. It may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fireplace and chimney, and (*f*) a window at least 9 square feet in area, made to open. The window of a back cellar let or occupied along with a front cellar need only be 4 square feet in area.

Any person who lets, occupies, or knowingly suffers to be occupied for hire or rent any cellar contrary to the Act is liable for every offence to a penalty not exceeding 20*s*. for every day of default (sec. 73). Where two convictions relating to the occupation of a cellar as a separate dwelling have taken place within three months, a Court of Summary Jurisdiction may close, either temporarily or permanently, the premises, as it deems to be necessary (sec. 75).

In the Metropolis, the provisions as to cellar dwellings by secs. 96 to 98 of the P.H. (London) A., 1891, differ somewhat from those given in the preceding section. A cellar dwelling or underground room must not be occupied in London unless:—(*a*) Every part is 7 feet high, and the ceiling is at least 3 *feet* above the surface of the adjoining street; but if the area outside is as much as 6 feet in width, or not less wide than the depth of the floor below the ground level, then the height may be 1 foot above the street. (*b*) Every wall has a damp-course, and, if in contact with the soil, is effectually secured from damp from the soil. (*c*) There is an open area outside along the frontage,

4 *feet wide* in every part, and 6 *inches* below the floor level. It may be crossed by steps, but not opposite a window. (*d*) The area and the soil immediately below the room are effectually drained. (*e*) The hollow space (if any) below the floor is ventilated to the outer air. (*f*) Any drain passing under the room is properly constructed of gas-tight pipe. (*g*) The room is effectually secured against the rising of any effluvia or exhalation. (*h*) There is a proper water-closet and ashpit in a convenient place. (*i*) There is effectual ventilation. (*j*) There is a fireplace, with chimney. (*k*) There are one or more windows opening directly into the open air; the window-area being at least one-tenth of the floor area, and so constructed that at least half of each window can be opened, and in each case opening to the top.

The same conditions apply to underground rooms occupied separately as dwellings before January 1, 1892; but the S.A., either by general regulations or upon special application by the owner, may modify any conditions newly imposed by this Act which involve structural alteration of the building. The power as to closure of underground rooms after two convictions is the same as under the 1875 Act.

Common Lodging-houses.—The expression "common lodging-house" is taken to mean, for the purposes of the P.H.A., 1875, those lodging-houses "in which persons of the poorer class are received for short periods and, though strangers to each other, are allowed to inhabit one common room." The term does not include inns, nor lodgings let to the middle or upper classes. Sec. 76 of P.H.A., 1875, requires every S.A. to keep a register of common lodging-houses in their district, in which shall be entered the names and addresses of the keepers thereof, and the situation of every such house, and the number of persons authorized by such authority to be received therein. Under the P.H.A. (Amend.) A., 1907, the S.A. can refuse the registration of a common lodging-house keeper, notwithstanding the production of a certificate signed by three ratepayers. Further, the S.A. must keep a register of keeper's deputies. The registration of keepers and their deputies needs renewal annually. No common lodging-house can be kept unless registered, and this can only be done after inspection and approval by some officer of the S.A. (P.H.A., 1875, secs. 77, 78). Before premises are so approved they should "(1) Possess the conditions of wholesomeness needed for dwelling-houses in general; and (2) should have arrangements fitting it for its special purpose of receiving a number of lodgers." Thus, the house should have dry foundations, and have proper drainage, guttering, and spouting, with a

well-laid and paved yard abutting on it. The drains must be properly connected, the soil-pipe ventilated, the water-closets trapped, and all waste-pipes from sinks, basins, etc., discharging over gullies outside the house. The closets, privies, and receptacles should be in convenient situations, of proper construction, and adapted to the scavenging arrangements of the district. The walls, roof, and floors should be in good repair. Inside walls should not be papered. Every registered room should have special means of ventilation, by chimney if possible, and a window opening freely and directly upon the outer air. There should be kitchen and day-room accommodation apart from the bedrooms. Rooms partially underground should not be registered as sleeping-rooms. There should be a supply of pure water, allowing at least 10 gallons per head per day for the maximum number of inmates, and one closet for every 20 registered lodgers. The washing accommodation should, wherever practicable, be in a special place, and not in the bedrooms; the basins for personal washing being fixed, trapped, and fitted with disconnected waste-pipes.

All common lodging-houses must have their walls and ceilings limewashed in the first weeks of April and October in each year (sec. 82). Free access must be allowed to officers of the S.A. to all parts of a common lodging-house. Under sec. 80 P.H.A., 1875, every S.A. must make bye-laws for the sanitary control and management of common lodging-houses: the following is a summary of the models issued:—

"(*a*) A greater number of lodgers than the maximum from time to time fixed by the S.A. by a notice served on the keeper of the house must not be accommodated in each room; it is usual to require at least 300 cubic feet of air space per head, but to count two children as one adult. (*b*) In general, no person above 10 years of age must occupy the same sleeping-room as persons of the opposite sex, but rooms may be set apart for the sole use of married couples, to the exclusion of other persons over 10 years of age, on condition that every bed is screened off. No bed must be occupied by more than one male above 10 years of age. (*c*) The yards, etc., must be kept clean and in good order; all floors swept daily, and washed once a week; all windows, painted surfaces, and fittings of wood, stone, or metal kept clean. (*d*) Closets must be kept clean and in good and efficient order. (*e*) Ashpits must be kept clean and in good order; no filth or wet refuse being thrown into ashpits designed for dry refuse only. (*f*) The windows must be opened fully for an hour in the morning and an hour in the afternoon, except in case of bad weather or occupation of the room by a sick person, or other

sufficient cause. Beds must be stripped of clothes and fully exposed to the air for an hour each day, and must not be re-occupied within 8 hours after being vacated. All refuse and slops must be removed every day before 10 a.m., and all utensils cleansed daily. Every sleeping-room must be provided with sufficient bedsteads, beds, bed-clothes, and utensils for the use of the maximum number of lodgers to be received therein. (*g*) A sufficient supply of suitable basins, water, and towels must be provided for the use of lodgers, and must be kept clean and renewed as required. (*h*) If the keeper finds that any lodger is suffering from an infectious disease, he must at once take all necessary precautions. No person, except a relative or attendant, must occupy the same room as the sick person. If the patient is removed to hospital by the S.A., the keeper must afford all facilities for removal, and must adopt all precautions directed by the M.O.H. He must, if required to do so, temporarily cease to receive lodgers into any infected room. At the end of the case, by removal, recovery, or death, the keeper must at once give notice to the M.O.H., and must cleanse and disinfect every part of the infected rooms and their contents, and in doing so must comply with all the instructions of the Health Officer. When the cleansing and disinfection are completed, he must give notice thereof to the M.O.H., and must not receive any lodger into the rooms in question until two days after such notice has been given. (*i*) A copy of the bye-laws in force with respect to common lodging-houses, supplied by the S.A., and a statement of the provisions of secs. 75 to 89 of the P.H.A., 1875, must be placed in some conspicuous place in the house, and must not be concealed, altered, obliterated, or injured." If the keeper of a common lodging-house fails to give notice of the occurrence of any infectious disease, he is liable to a penalty under sec. 84 of P.H.A., 1875. As regards houses let in lodgings or occupied by members of more than one family, any S.A. may make bye-laws, under sec. 90 P.H.A., 1875, as modified by sec. 8 of H.W.C.A., 1885.

Housing of Working Classes.—A considerable amount of legislature exists as to this question. Under the H.W.C.A., 1885, every S.A. must exercise powers which they possess under the P.H.A., 1875, to secure a proper sanitary condition of *all* premises within their area. Powers of entry to inspect suspected premises between the hours of 6 a.m. and 9 p.m. is given to any person authorized by the S.A. or by a magistrate, by sec. 9, H.W.C.A., 1885. As regards the pulling down of unhealthy areas, full powers are given by Part i. of H.W.C.A., 1890. After complaint, inspection is to be made, and due publicity given as to

any scheme of amendment. If the scheme be confirmed by the M.H., application is made to Parliament for a provisional order. After this order is confirmed by Parliament, it is executed by the S.A., who must take care to adjudicate claims for compensation, and, if necessary, submit them to arbitration. In London accommodation *must* be provided in or near the area for the whole population displaced, unless the provisional order decrees otherwise; outside the metropolis such provision is only compulsory if and to the extent provided by the order.

As regards unhealthy or obstructive buildings, similar powers are given and to be carried out, subject to the concurrence of M.H., under Part ii. of the H.W.C.A., 1900. In rural districts, information of proceedings about to be taken must be sent to the County Council by a S.A. instigating proceedings for either closing or demolition. Similarly, a County Council can compel a S.A. to proceed, or can take over and exercise the powers of a S.A. failing to act, and recover expenses from the S.A. concerned. Under House, Town Planning Act, 1909, it is compulsory on S.A. to adopt Part iii. of the H.W.C.A., 1890, formerly adoptive. This authorizes every S.A. to provide lodging-houses for the working-classes, subject to sanction of M.H., in urban districts, and the County Council in rural. The H.W.C.A., 1900 and 1903, deal with and simplify the terms on which the S.A. acquire land for improvement of this kind. Under H.T.P.A., 1909, the facilities for acquiring land are still further increased, and its object is to ensure, by schemes prepared by the S.A. or landowner, that land in the vicinity of towns shall be developed in such way as to secure proper sanitary conditions and convenience in connection with laying out of land and building thereon. Its essential feature and object is to improve the relations between landowners and the S.A., and also to enable each to co-operate with the other in promoting the public interests.

A recent amplification of the foregoing legislation is the Housing and Town Planning Act of 1919. It applies to England and Wales, and orders every S.A. to prepare and submit, within three months after notice by M.H., a scheme under Part iii. of the principal Act, 1900, specifying the approximate number and nature of houses to be provided by the local authority, the approximate quantity of land required, the average number of houses per acre, the cost and time within which the scheme is to be completed. S.A.'s may make joint schemes. The M.H. may approve or modify the schemes as they think fit. In the case of defaulting local authorities, the County Council may be authorized to act and charge expenses to the defaulting S.A. Under these schemes, existing bye-laws may be relaxed if plans and specifica-

tions are approved by the M.H. The powers under P.H.A., 1875, which refer to *houses let in lodgings* shall, in the case of houses so occupied by the working classes, be extended so as to provide for adequate or separate provision for each family of w.c. accommodation, water supply, and washing facilities, accommodation for storage, preparation, and cooking of food. Also for adequate lighting and keeping in repair any common stair, the provision of handrails for all staircases, prevention and safety from fire, the adequate lighting of any room, paving of courts or yards, and cleaning or redecoration at stated times. On application by a S.A. a county court may authorize conversion of a house into several tenements, notwithstanding any restrictive covenant.

Factories and Workshops.—The general effect of the Factories and Workshop Act, 1901, is to place all factories and workshops under a dual control, namely, the Home Office and the various sanitary authorities. The Home Secretary appoints factory inspectors, whose primary duty is to inspect *factories*, while the primary duty of inspecting *workshops* and workplaces rests with the S.A.

By the Factory and Workshop Act, 1901, *factories* include (1) all places in which mechanical power is used in aid of the manufacturing process; and (2) the following, whether power be used or not:—print-works, bleaching and dye-works, earthenware works, lucifer-match works, percussion-cap works, cartridge works, paper-staining works, fustian-cutting works, blast-furnaces, copper mills, iron mills, foundries, metal and india-rubber works, paper mills, glass-works, tobacco factories, letterpress printing works, bookbinding works, flax scutch mills, electrical stations.

Factories and workshops, be they wholesale, retail, or subcontracting, may be (1) those in which "protected persons" are employed, that is, a child under 14 or a young person over 14 but under 18, or a woman over 18 years of age; (2) those in which "protected persons" are not employed; (3) tenement factories or workshops; and (4) domestic factories and workshops.

A "*tenement factory*" is one in which mechanical power is supplied to different parts of the same building occupied by different persons, for the purpose of any manufacturing process or handicraft in such manner that these parts constitute in law separate factories.

Domestic factories and *Domestic workshops* are those carried on in private houses, without use of mechanical power, where the only persons employed are members of the same family dwelling there. If any work certified by the Home Secretary to be

dangerous is carried on, they are treated as ordinary factories and workshops; otherwise they are, so far as sanitation is concerned, treated as ordinary workshops, except that the requirements as to general ventilation and drainage of floors do not apply. The following, if carried on under conditions which would otherwise make the premises a domestic workshop, are exempted:—(1) Straw-plaiting, pillow-lace making, glove-making; (2) work done at irregular intervals, and not furnishing the principal means of living to the family.

Workshops include (1) the following, unless they are factories by reason of the use of mechanical power:—hat-works, rope-works, bakehouses (any places in which are baked bread, biscuits, or confectionery, from the baking or selling of which a profit is derived), lace warehouses, ship-building yards, quarries, pit-banks of metalliferous mines, dry-cleaning works, carpet-beating works, and bottle-washing works; (2) premises (not being factories) in which manual labour is exercised by way of trade or for purposes of gain, in or incidental to the making, altering, repairing, ornamenting, finishing or adapting for sale of any article, if the employer has the right of access or control; (3) tenement workshops; that is, workplaces in which, "with the permission of or under agreement with the owner or occupier, two or more persons carry on any work which would constitute the workplace a workshop if the persons working therein were in the employment of the owner or occupier." Instances of tenement workshops are the Sheffield file-cutting shops, where file-cutters work on their own account; also journeymen tailors' workshops, where men hire a separate sitting or place to work from the owner or occupier.

Men's workshops (those in which only males over eighteen are employed) are exempted from several of the provisions of the Act, including those relating to general ventilation, temperature, drainage of floors, sanitary accommodation, lavatories, fans for removal of dust or fumes, and means of escape from fire.

Crown factories and workshops are excluded from the jurisdiction of the S.A.

Workplace is not defined, but has a wider meaning than workshop, and has been held to include any place where people assemble together to do work permanently, *e.g.* a stable and stable-yard, where men are employed as cab-cleaners and horse-keepers.

In factories, sanitation generally is enforced by the Factory Inspector, not by the District Council, hereafter referred to as the Sanitary Authority, but the latter deals with the means of escape from fire (in London this rests with the County Council), and have

special duties in connection with bakehouses and domestic factories, as well as with sanitary accommodation under sec. 9 of the Factory Act, 1901, also under sec. 38 of the P.H.A., 1875, and where Part III. of the P.H. (Amend.) A., 1890, is in force, under sec. 22 of that Act. If any act or default, punishable or remediable under the P.H.A., but not under the Factory Act, is found by the Factory Inspector in a factory or workshop, he is to report it to the S.A., who must make inquiry, take such action as may seem proper, and inform the Factory Inspector what has been done. If proceedings are not taken by the S.A. within a month, the Factory Inspector may institute proceedings in default, and recover from the S.A. any expenses not recovered from other persons, and not incurred in unsuccessful proceedings (sec. 5). If the S.A. fail generally to carry out their duties with regard to factories, workshops, or workplaces, the Home Secretary may authorize the Factory Inspector to act in default for a specified period, and the expenses not recovered from other persons may be recovered from the S.A.

In workshops and workplaces the S.A. (secs. 2, 3, 4 and 5) is primarily responsible for enforcing sanitary requirements generally, and means of escape from fire; and their officers have the same powers of entry, inspection, and legal proceedings as Inspectors of Factories. Certain sanitary requirements, however, more particularly those relating to temperature, fans for removal of dust and fumes, and those arising under the Factory Act (as distinguished from the powers of the S.A. under the P.H.A., 1875) with regard to sanitary accommodation are enforced by the Factory Inspectors. The S.A. is required to keep a register of all workshops in its district (sec. 131). If the M.O.H. finds any woman, young person, or child employed in a workshop in which no abstract of the Factory Act is affixed, he is required to inform the Factory Inspector. The occupier of a new factory, workshop, or laundry must notify the Factory Inspector, who, in the case of a workshop, forwards the notice to the S.A.

The M.O.H. (under sec. 132) is required in his annual report to report specifically upon the administration with regard to workshops and workplaces, and to send a copy to the Home Secretary. A table issued by the M.H. for the guidance of the M.O.H., includes the items calling for statistical record.

Outside the Factory Act, the S.A. is concerned with certain factories and workshops on public health grounds, as sources of smoke, poisonous fumes, trade effluents; as places where offensive trades or food manufacture needing control are carried on; as new buildings needing approval of plans, or old buildings in a

dangerous state; or more indirectly as places in which infection may be spread from one person to another, or (as in laundries) infected articles may be handled. Nor are these the only points claiming the attention of the various officials of the S.A. in connection with plans for new factories and workshops. Others are strength of foundations and structure generally where heavy machinery is to be fixed; means of escape from fire; sanitary accommodation. Others, again are the statutory requirements as to air space, ventilation and warming; the surfaces of walls and ceilings must be such as to admit of due cleansing, and the proper construction of floors (soundness, impermeability, slope, drainage) is of importance in certain processes. In certain dangerous trades additional structural requirements arise, and in some the plans have also to be approved by the Chief Inspector of Factories.

The requirements of the Factory and Workshop Act, 1901, in the above-mentioned matters, and which it is the duty of the S.A. to enforce, are as follows:—

Cleanliness.—By sec. 2 every workshop and workplace must be kept in a cleanly state, and if not so kept may be dealt with as a nuisance under the P.H.A. A workshop or any specified part thereof (in London this power extends to domestic factories and to workplaces, P.H. (L.) A., 1891, sec. 25) must be limewashed, cleansed or purified when so required, by notice from the S.A., on the certificate of the Medical Officer or Sanitary Inspector that it is necessary for the health of the workers. All factories must be kept in a cleanly state, and (subject to certain exceptions) either (*a*) limewashed every fourteen months, or (*b*) painted with oil or varnished every seven years, and washed with soap and hot water every fourteen months. For the cleaning of floors, etc., damp processes are preferable, as checking the production of dust.

Air Space.—Factories, workshops and workplaces (secs. 2 and 3) must not be so overcrowded as to be dangerous or injurious to the health of the workers, and there must be at least 250 cubic feet of air space for each worker; during overtime for women 400 cubic feet must be provided, 500 cubic feet in underground bakehouses, 400 cubic feet between 9 p.m. and 6 a.m. in other bakehouses with light other than electric, 400 cubic feet in workshops (not domestic) used also as sleeping-rooms. The air space of each workroom must be stated in a notice affixed in the works. A much larger air space is required in certain dangerous trades, and in works where certain special exceptions are permitted, *e.g.* in match factories in which yellow phosphorus is used the minimum is 400 cubic feet, and height above 14 feet is not counted, and in engineering works exemption from routine

annual limewashing is allowed if the air space be 2500 cubic feet per head.

General Ventilation (sec. 7) must be efficient in every workroom of a factory or workshop (other than a men's workshop), and any standard fixed by the Home Secretary must be observed; thus, a limit of 9 volumes of carbon dioxide per 10,000 of air in humid cotton-cloth factories is required, and 600 cubic feet of fresh air per head per hour must be supplied in other humid textile factories. Air samples are taken usually at the breathing-level, at points when work is carried on, and not in extreme corners or near to inlets or outlets, or close to persons or to sources of carbon dioxide. In breweries, aerated water factories, bakehouses, etc., where carbonic acid is given off by trade processes, allowance has to be made; and similarly where artificial lighting yields carbon dioxide. As a rule, it is well to make a parallel determination in the open air.

Local Ventilation, for removal of dust, gases, vapours, or other impurities generated in the course of work, which are a nuisance or injurious to health, must be such as to render them harmless as far as possible. Usually this involves exhaust ventilation, applied at or near the point of origin; and fans (or other efficient mechanical means) for the purpose are prescribed in certain dangerous processes, and can be required by the Factory Inspector in others. Exhaust ventilation may sometimes be secured by connection with flues or other heated shafts, but in general fans are required, and need careful planning. The essentials are that the dust or fumes should be intercepted as near as possible to their source, and carried away from the workers, without entering the general air of the room; that the draught should be adequate for the purpose, and guided where necessary by hoods; and that the air-ducts should be kept clean and discharge at a suitable point, preferably in a closed dust-chamber. As a rule, a downward draught is best, since it carries away the dust more readily. The efficiency of exhaust can be tested by anemometers or by smoke, light dust, or fumes of ammonium chloride. In some instances, standards are fixed, in terms of sectional area of openings and velocity at given points. Other measures are the use of closed chambers or boxes, and as regards dust the adoption of wet processes, handling the dusty materials over gratings through which the dust can fall, cleanliness of premises and floors, and the use of overalls.

Temperature.—In every workroom of a factory or workshop provision must be made for securing a reasonable temperature (sec. 6), and without interfering with the purity of the air of the room. This requirement is enforced by the Factory Inspector.

Gas-jets cannot be accepted as means of warming, nor must the ventilators be closed. As a lower limit 60° F. is suitable for sedentary occupations, but active work can be carried on at a lower temperature. The upper limit is not easily defined, since in certain processes a high temperature is a trade necessity, while in others it is only accidental. In humid cotton-cloth factories it is forbidden to raise the temperature artificially above 70° F., except so far as is necessary for moistening the air. If the air be dry, high temperatures can be borne, but as a rule where work is hard, high wet-bulb temperatures should be avoided. Humidity is expressly regulated in textile factories generally, such as spinning- and weaving-sheds where the air is moistened by steam jets or otherwise to facilitate the efficient working and treatment of the cotton fibres. In these places a limit of humidity is fixed for each dry-bulb degree, thus 88 per cent. from 59° to 70° F., decreasing thence to 77·5 per cent. at 80° F., 69 per cent. at 90° F., and 64 per cent. at 100° F. In certain textile processes, however, a difference of 2° between wet and dry bulbs is accepted at all temperatures. Hygrometers must be affixed in each room, and (except in cotton-spinning mills), records kept of two (in cotton-cloth factories three) daily readings at 7 to 8 a.m., 10 to 11 a.m. and 3 to 4 p.m. The water used for humidification must be taken either from a pure source or be effectively purified; a water which gives off an offensive smell on being heated, or which absorbs more than 0·5 mgm. of oxygen from an acid solution of potassium permanganate in two hours at 60° F. is to be regarded as unsuitable. Owing to the clothing of workers becoming damp in moist air warmed ventilated cloak rooms are obligatory in new-built humid cotton weaving sheds.

Sanitary Accommodation.—The following are the provisions made in regard to these matters by an Order of the Home Secretary, under sec. 9 of the Act:—

"1. In factories or workshops where females are employed or in attendance there shall be one sanitary convenience for every twenty-five females.

"In factories or workshops where males are employed or in attendance there shall be one sanitary convenience for every twenty-five males; provided that (*a*) in factories or workshops where the number of males employed or in attendance exceeds one hundred, and sufficient urinal accommodation is also provided, it shall be sufficient if there is one sanitary convenience for every twenty-five males up to the first hundred and one for every forty after; (*b*) in factories or workshops where the number of males employed or in attendance exceeds five hundred, and the district Inspector of Factories certifies in writing that by

means of a check system, or otherwise, proper supervision or control in regard to the use of the conveniences are exercised by officers specially appointed for that purpose, it shall be sufficient if one sanitary convenience is provided for every sixty males, in addition to sufficient urinal accommodation. Any certificate given by an Inspector shall be kept attached to the general register, and shall be liable at any time to be revoked by notice in writing from the Inspector. In calculating the number of conveniences required by this Order, any odd number of persons less than twenty-five, forty, or sixty, as the case may be, shall be reckoned as twenty-five, forty, or sixty.

"2. Every sanitary convenience shall be kept in a cleanly state, shall be sufficiently ventilated and lighted, and shall not communicate with any workroom except through the open air or through an intervening ventilated space; provided that in workrooms in use prior to January 1, 1903, and mechanically ventilated in such manner that air cannot be drawn into the workroom through the sanitary convenience, an intervening ventilated space shall not be required.

"3. Every sanitary convenience shall be under cover and so partitioned off as to secure privacy, and if for the use of females, shall have a proper door and fastenings.

"4. The sanitary conveniences in a factory or workshop shall be so arranged and maintained as to be conveniently accessible to all persons employed therein at all times during their employment.

"5. Where persons of both sexes are employed, the conveniences for each sex shall be so placed or so screened that the interior shall not be visible, even when the door of any convenience is open, from any place where persons of the other sex have to work or to pass; and, if the conveniences for one sex adjoin those for the other sex, the approaches shall be separate."

Safety from Fire.—By secs. 14 and 15 it is the duty of a District Council, and in London the duty of the County Council, to see that every factory and workshop in its district is provided with sufficient means of escape in case of fire.

Home Work.—Very important powers of controlling the conditions under which certain classes of work are done in the homes of the workers are given to S.A. by secs. 107 to 115 of the Factory Act, 1901. These powers aim at the prevention of home work being done (1) in dwellings which are injurious or dangerous to the health of the workers themselves; (2) in premises where there is infectious disease. The employer must keep lists of the names and addresses of the out-workers, and send copies to the S.A. of his district on or before February 1

and August 1 of each year, in a prescribed form. If any such addresses are outside the area of the authority, particulars of them must be sent by the S.A. to the authority concerned. If the home premises are injurious or dangerous (overcrowding, want of ventilation, or other insanitary condition) to the health of the workers, the S.A. may prohibit the employer giving out the work to be done there. This power may be exercised also in the case of work given out from places other than factories or workshops, as, for instance, shops, warehouses or laundries. The power does not apply to all classes of home work, but only to those which may be specified by Orders of the Home Secretary. The trades scheduled by Orders of August, 1905, and May, 1907, and to which the power is rendered applicable, are the following classes of work: the making, cleaning, washing, altering, ornamenting, finishing and repairing of wearing apparel, and any work incidental thereto; the making, ornamenting, mending and finishing of lace, and of lace curtains and nets; cabinet and furniture making and upholstery work; the making of electro-plate; the making of files; fur-pulling; the making of iron and steel cables and chains; the making of iron and steel anchors and grapnels; the making of cart-gear, including swivels, rings, loops, gear-buckles, mullin-bits, hooks, and attachments of all kinds; the making of locks, latches, and keys; the making of covers for and finishing of umbrellas, sunshades, parasols; the making of cardboard or paper boxes and paper bags; brush making and the making of stuffed toys; the making of artificial flowers, or pea picking and feather sorting. Wearing apparel and upholstery may not be made, cleansed, or repaired by out-workers in any house where there is a case of small-pox or scarlet fever. If an inmate of a house is suffering from a notifiable infectious disease, no matter if removed, the S.A. can prohibit the employer from giving out work in respect of any of the foregoing scheduled classes of work to be done in that home or house, or in any specified part of it, during a specified period.

An out-worker is one who works outside the factory, that is, receives work from a factory to do at home or in another workshop. He is also called a home-worker. The M.O.H. must give notice to the Factory Inspector for the district of any "protected person" employed in a workshop. Lists giving the names and addresses must be kept by occupiers of factories or workshops of all out-workers, and these lists sent to the factory inspector and to the Council of the district and S.A. where the factory or workshop is situated on February 1st and August 1st every year.

Laundries are technically workshops, and as regards sanitation, under the F. and W.A., 1907, are subject to the same

requirements as other workshops under the Act of 1901. This includes all laundries used by way of trade or auxiliary to charitable institutions. They are also open to Government inspection. In addition to the sanitary requirements laid down for factories and workshops, in factory laundries fans are required for regulating the temperature of ironing rooms and for removing steam from wash-houses; stoves for heating irons must be separated from the ironing rooms, and gas-irons emitting noxious fumes must not be used; floors must be kept in good condition, and so drained as to allow the water to flow off freely.

Among other provisions of the Factory Act, bearing upon the well-being of the worker, may be mentioned those relating to safety from machinery, accidents, age and sex of those employed, and the hours and intervals for work and rest. Children under 12 years of age may not be employed in factories or workshops. Above 12, they may be employed for half-time (if they have attained a certain standard, and if the local educational bye-laws permit), but must attend school for the other half. In factories they must have a certificate of fitness (as to age and physique) from the certifying surgeon, which may be coupled with conditions as to the nature of the employment allowed. "Young persons" are those between 14 and 18 (or between 13 and 14, subject to conditions as to educational certificates), and are eligible for full-time employment, with certain limitations. Certificates of fitness are required for those under 16 employed in factories. A woman must not be employed within four weeks after giving birth to a child.

Offensive Trades.—The "offensive trades" are defined by sec. 112, P.H.A. 1875, and sec. 51, P.H. (Amend.) Act, 1907, as those of bloodboiler, bone-boiler, soapboiler, fellmonger, tallow-melter, tripe-boiler, and any other trade, business, or manufacture which the S.A. declare by Order confirmed by the M.H., and published in such manner as the Board direct, to be an offensive trade.

An urban S.A. may make bye-laws with respect to these trades, when they have been established with their consent, so as to prevent or diminish any nuisance arising therefrom (sec. 113); but a rural authority would have to apply to the M.H. for power, under sec. 276, to apply these provisions.

Model Bye-laws have been issued in regard to not only the six trades mentioned in sec. 112 of the Act of 1875, but also in reference to the trades of a leather-dresser, tanner, fat-melter or fat-extractor, glue-maker, size-maker, blood-drier, and gut-scraper. The same general provisions appear in all, with numerous additions or variations as required by the conditions of the

particular trade in question. The following summary will show their general scope and character:—

"(*a*) All materials not required for immediate use or treatment shall be so stored as to prevent effluvium. (*b*) The best practicable means must be adopted for rendering any offensive vapours emitted during melting, boiling, etc., innocuous. The vapour must be either discharged into the external air in such a manner and at such a height as to admit of its diffusion without injurious effects; or shall be passed directly from the pan, etc., through a fire; or into a condensing apparatus; or through a condensing apparatus and then through a fire; in such a manner as effectually to consume the vapour or deprive it of all noxious or injurious properties. (*c*) The drainage on the premises must be kept in efficient order. Bone-boilers must cool all hot liquid refuse before passing it into any drain. (*d*) Floors must be kept in good order so as to prevent the absorption of filth. In the majority of these trades it is advisable to require the floors to be either swept, washed, scraped, or otherwise cleansed at the close of every working day. All refuse so collected, by scraping or sweeping, shall be removed forthwith from the premises in covered receptacles, unless intended to be forthwith subjected to further trade processes on the premises. (*e*) Walls must be kept in good order so as to prevent the absorption of filth, and, if necessary, be scraped. Limewashing of walls and ceilings twice a year is necessary in regard to these trades. (*f*) All apparatus, including implements and vessels, must be kept clean; where possible, this should be done daily. (*g*) Waste lime resulting from the businesses of fellmongers and tanners must be removed at once, and under close cover. (*h*) Tanks used by fellmongers for washing or soaking skins must be emptied and cleansed as often as may be necessary to prevent effluvia. (*i*) Every facility must be allowed for the access to the premises of the Medical Officer of Health, Inspector of Nuisances, Surveyor, or any Committee appointed by the authority, for the purpose of inspection at all reasonable times."

Section 114 enacts that, if the M.O.H., or two legally qualified medical practitioners, or ten inhabitants of a district, certify that any of the following places are a nuisance, or injurious to health, it is the duty of the S.A. to take proceedings against the offender, who is liable to a penalty not exceeding £5, nor less than 40*s*., unless he can show that he has used the best practical means for abating such nuisance, or preventing or counteracting such effluvia. The premises mentioned in this section are "any candle-house, melting-house, melting-place, or soap-house, or any slaughter-house, or any building or place for boiling offal

or blood, or for boiling, burning, or crushing bones, or any manufactory, building, or place used for any trade, business, process, or manufacture causing effluvia." The same powers are applicable where a nuisance, affecting the inhabitants of a district, arises from offensive trades carried on in premises situated beyond the limits of the district (sec. 115).

Rag Flock.—The Rag Flock Act, 1911, prohibits any one selling or having in his possession for sale any flock manufactured from rags, or use for the making of any article of upholstery, cushions, or bedding, any such flock unless it conforms to such standard of cleanliness as may be prescribed by Regulation. The existing Regulations, issued in 1912, require that the amount of soluble chlorine, as chlorides, removed by thorough washing with distilled water at a temperature not exceeding 25° C., from not less than 40 grammes of a well-mixed sample of flock shall not exceed 30 parts of chlorine in 100,000 parts of the flock.

Slaughter-houses are defined by sec. 4, P.H.A., 1875, and sec. 169 of the same Act empowers any urban S.A. to provide abattoirs or slaughter-houses, and also license those belonging to private owners. The S.A. must make bye-laws for the licensing and inspection of slaughter-houses and knackers' yards, preventing cruelty therein, keeping the same clean, for the daily removal of filth, and for the proper supply of water. The following model bye-laws are applicable to these requirements:—

"(*a*) *Licences.*—Applications for licence of existing premises, or erection of new slaughter-houses, must be made upon a specified form, and must include full particulars as to the position, form, area, cubic space, etc., of the buildings and appendages; materials and construction of walls and floors; means of water-supply, drainage, lighting, and ventilation; means of access for cattle; number, position, and size of stalls or lairs, and number of animals to be accommodated therein, distinguishing oxen, calves, sheep, and swine. The boundaries must also be shown, and, in the case of old premises, particulars as to the ownership and the applicant's tenure must be given. The areas where the P.H. (Amend.) A., 1890, has been adopted the licence shall run for one year only, or such period as the S.A. shall specify in the licence. If the licensee is convicted under secs. 116–119 of the P.H.A., 1875, a court of justice may revoke the licence.

"(*b*) *Registration.*—If the Sanitary Authority approve the application, a licence shall be issued to the applicant, and must be registered by him at the office of the Sanitary Authority.

"(*c*) *Inspection.*—Free access to every slaughter-house for the purpose of Inspection must be afforded at all reasonable times

to the Medical Officer of Health, Inspector, Surveyor, and Committees appointed by the Sanitary Authority.

"(*d*) *Water* must be supplied to every animal kept in a lair prior to slaughter.

"(*e*) *Mode of Slaughter.*—Cattle must be secured by the head so as to be felled with as little pain as practicable.

"(*f*) *Drainage, water-supply, and ventilation* must be kept in efficient order.

"(*g*) *Cleanliness.*—The walls and floor must be kept in good order and repair, and must be thoroughly cleansed within three hours after any slaughtering; the walls and ceiling must be limewashed four times yearly, that is to say, within the first ten days of March, June, September, and December respectively.

"(*h*) *Animals not to be kept.*—No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting or otherwise.

"(*i*) *Removal of Refuse.*—Suitable vessels made of non-absorbent materials, and provided with close-fitting covers, must be provided for the reception of blood, manure, garbage, and other refuse. All such matters must be placed in these vessels immediately after the slaughtering. The refuse must be removed within twenty-four hours, and the vessels forthwith cleansed. All skins, fat, and offal must be removed within twenty-four hours."

Alkali and Chemical Works.—These are inspected and regulated by the M.H., under the Alkali Works Act, 1906. The following processes of manufacture come under this Act:—

"(1) Alkali works, that is to say, every work for (*a*) the manufacture of sulphate of soda or sulphate of potash, or (*b*) the treatment of copper ores by common salt or other chlorides, whereby any sulphate is formed, in which muriatic acid gas is evolved. (2) Cement works. (3) Smelting works, that is to say, works in which sulphide ores, including regulars, are calcined or smelted. (4) Sulphuric acid works, that is to say, works in which the manufacture of sulphuric acid is carried on by the lead chamber process, namely, the process by which sulphurous acid is converted into sulphuric acid by the agency of oxides of nitrogen and by the use of a lead chamber. (5) Sulphuric acid works, that is to say, works in which the manufacture of sulphuric acid is carried on by any process other than the lead chamber process, and works for the concentration or distillation of sulphuric acid. (6) Chemical manure works, that is to say, works in which the manufacture of chemical manure is carried on, and works in which any mineral phosphate is subjected to treatment involv-

ing chemical change through the application or use of any acid. (7) Gas liquor works, that is to say, works (not being sulphate of ammonia works or muriate of ammonia works) in which sulphuretted hydrogen or any other noxious or offensive gas is evolved by the use of ammoniacal liquor in any manufacturing process, and works in which any such liquor is desulphurised by the application of heat in any process connected with the purification of gas. (8) Nitric acid works, that is to say, works in which the manufacture of nitric acid is carried on, and works in which nitric acid is recovered from oxides of nitrogen. (9) Sulphate of ammonia works and muriate of ammonia works, that is to say, works in which the manufacture of sulphate of ammonia or of muriate of ammonia is carried on. (10) Chlorine works, that is to say, works in which chlorine is made or used in any manufacturing process. (11) Muriatic acid works, that is to say, (*a*) Muriatic acid works, or works (not being alkali works as defined in this Act) where muriatic acid gas is evolved either during the preparation of liquid muriatic acid or for use in any manufacturing process; (*b*) tin-plate flux works, that is to say, works in which any residue or flux from tin-plate works is calcined for the utilization of such residue or flux, and in which muriatic acid gas is evolved; and (*c*) salt works, that is to say, works (not being works in which salt is produced by refining rock salt, otherwise than by the dissolution of rock salt at the place of deposit) in which the extraction of salt from brine is carried on, and in which muriatic acid gas is evolved. (12) Sulphide works, that is to say, works in which sulphuretted hydrogen is evolved by the decomposition of metallic sulphides, or in which sulphuretted hydrogen is used in the production of such sulphides. (13) Alkali waste works, that is to say, works in which alkali waste or the drainage therefrom is subjected to any chemical process for the recovery of sulphur or for the utilisation of any constituent of such waste or drainage. (14) Venetian red works, that is to say, works for the manufacture of Venetian red, crocus, or polishing powder, by heating sulphate or some other salt of iron. (15) Lead deposit works, that is to say, works in which the sulphate of lead deposit from sulphuric acid chambers is dried or smelted. (16) Arsenic works, that is to say, works for the preparation of arsenious acid, or where nitric acid or a nitrate is used in the manufacture of arsenic acid or an arseniate. (17) Nitrate and chloride of iron works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of nitrate or chloride of iron. (18) Bisulphide of carbon works, that is to say, works for the manufacture of bisulphide of carbon. (19) Sulpho-cyanide works, that is to say, works in which the manufacture of any sulpho-cyanide is carried on by the reaction

of bisulphide of carbon upon ammonia or any of its compounds. (20) Picric acid works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of picric acid. (21) Paraffin oil works, that is to say, works in which crude shale oil is refined. (22) Bisulphite works, that is to say, works in which sulphurous acid is used in the manufacture of acid sulphites of the alkalis or alkaline earths. (23) Tar works, that is to say, works where gas-tar or coal-tar is distilled or is heated in any manufacturing process. (24) Zinc works, that is to say, works in which, by the application of heat, zinc is extracted from the ore, or from any residue containing that metal."

The following are the requirements of the Act of 1906 with respect to alkali works. Every such work must be carried on in such a manner that 95 per cent. of the hydrochloric acid gas evolved must be condensed, and not more than $\frac{1}{5}$th of a grain of hydrochloric acid gas per cubic foot of air, smoke or chimney gases must escape from the works into the atmosphere. Nor must there be more of the acid gases of sulphur and nitrogen than the equivalent of 4 grains of sulphuric anhydride per cubic foot of air.

Acid drainage must not be allowed to mix with alkali waste so as to cause a nuisance. The owners of alkali works may require the S.A. to provide and maintain, at his expense, a drain for carrying the acid waste into the sea, or any watercourse into which it can be taken without breach of the Rivers Pollution Prevention Act, 1876. Alkali waste must not be deposited or discharged without the best practicable and available means being used to prevent nuisance. Similar regulations apply to sulphuric acid works. The gases escaping into the atmosphere must not have an acidity equivalent to more than 4 grains of sulphuric anhydride per cubic foot. The other works scheduled in the Acts must employ the best practicable means for preventing the escape of noxious and offensive gases, and for rendering them harmless and inoffensive, subject to the qualification in the case of sulphuric acid works as to the degree of aerial vitiation by the escaping gases.

APPENDIX.

MEASURES OF LENGTH.

THE **Standard Metre** is $\frac{443296}{864000}$ of the distance, at the temperature of 16·3° C., between the ends of a certain bar, called the "Toise of Peru," kept in the French Archives, and is approximately the ten-millionth part of the distance from one of the earth's poles to the Equator, at the meridian of Paris. This measure, and those founded on it, is lawful in this country, and a copy of the standard metre is kept in the Exchequer Office at Westminster.

The English **Standard Yard** is the distance, at the temperature of 62° F., between two marks on a certain bar which is kept in the office of the Exchequer.

The relative values of the Metric and English measures of length can be gathered from the following table:—

	Metres.	Inches.	Feet.	Yards.	Miles.
Kilometre	1000	—	—	—	0·6214
Hectometre	100	—	—	—	—
Decametre	10	—	—	—	—
Metre	**1**	**39·37**	**3·28**	**1·0936**	—
Decimetre	0·1	—	—	—	—
Centimetre	0·01	—	—	—	—
Millimetre	0·001	0·03937	—	—	—

MEASURES OF AREA.

	Square metres.	British measures of area.	
Square Kilometre	1000000	0·3861	sq. mile.
,, Hectometre, or Hectare	10000	2·4711	acres.
,, Decametre, or Are	100	119·6	sq. yards
,, **Metre**	**1**	**10·764**	sq. feet.
,, Decimetre	0·01	15·5	sq. inches.
,, Centimetre	0·0001	0·155	,,
,, Millimetre	0·000001	0·00155	,,

SOLID MEASURES.

1 Cubic Decametre, or Kilostere,	equals	35,316·5	cubic feet.
,, **Metre, or Stere,**	,,	**35·3**	,,
,, Decimetre, or Millistere,	,,	61·025	cubic inches.
,, Centimetre	,,	0·061	,,
,, Millimetre	,,	0·000061	,,

MEASURES OF WEIGHT.

The metric **Standard Kilogramme** is the weight, at the temperature of the maximum density of water (4° C.), and under the atmospheric pressure of 760 millimetres of mercury, in the latitude of Paris, of a certain piece of platinum which is kept in the French Archives. A copy of this standard kilogramme is kept in our Exchequer Office. The kilogramme was at first intended to be the weight of one cubic decimetre of pure water at its maximum density, but it is in actual fact slightly greater.

The English **Standard Pound Avoirdupois** is the weight, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury, in the latitude of London, and at or near the level of the sea, of a certain piece of platinum, which is kept in the Exchequer Office at Westminster.

The relative values of the Metric and English weights is shown in the following table :—

	Grammes.	Grains.	Avoir. ozs.	Avoir. lbs.
Kilogramme . .	**1000**	**15432**	**35·3**	**2·2**
Hectogramme . .	100	—	—	—
Decagramme . .	10	—	—	—
Gramme. . . .	1	15·432	0·0353	0·0022
Decigramme . .	0·1	—	—	—
Centigramme . .	0·01	—	—	—
Milligramme . .	0·001	0·0154	—	—

MEASURES OF CAPACITY.

The metric **Standard Litre** is the volume of a kilogramme of pure water at its temperature of maximum density (4° C.) and under the atmospheric pressure of 760 millimetres of mercury. It was originally intended to be a cubic decimetre, but is actually a little greater. Under the above-mentioned conditions, a litre of pure water weighs one kilogramme.

The English **Standard Gallon** is the volume of 10 lbs. avoirdupois of pure water, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury.

The relative values of the Metric and English measures of capacity is shown in the following table :—

	Cubic centimetres.	Fluid ozs.	Pints.	Gallons.	Cubic ins.
Kilolitre . . .	1000000	—	—	—	—
Hectolitre . .	100000	—	—	—	—
Decalitre . .	10000	—	—	—	—
Litre	**1000**	**35·3**	**1·76**	**0·22**	**61·027**
Decilitre . . .	100	—	—	—	—
Centilitre . .	10	—	—	—	—
Millilitre . . .	1	—	—	—	—

BRITISH WEIGHTS AND MEASURES.

Avoirdupois Weight.

16 drachms	1 ounce	28 pounds	1 qr.
16 ounces	1 pound	4 qr. or 112 lb.	1 cwt.
14 pounds	1 stone	20 cwt.	1 ton

Troy Weight.

3·17 grains	1 carat	12 ounces	1 pound
24 grains	1 dwt.	100 pounds	1 cwt.
20 dwt.	1 ounce		

Liquid Measure.

4 gills	1 pint	4 quarts	1 gallon
2 pints	1 quart		

Dry Measure.

2 pints	1 quart	2 bushels	1 strike
2 quarts	1 pottle	4 bushels	1 coomb
4 quarts	1 gallon	8 bushels	1 quarter
2 gallons	1 peck	5 quarters	1 load
4 pecks	1 bushel	10 quarters	1 last

Measures of Length.

12 inches	1 foot	6082·66 feet	1 naut. mile or knot
3 feet	1 yard	7·92 inches	1 link
2 yards	1 fathom	100 links, 66 feet, 22 yards	1 chain
5½ yards	1 pole		
22 yards	1 run		
220 yards	1 furlong		
8 furlongs, 1760 yards, 5280 feet	1 statute mile		

Square and Land Measures.

144 square inches	1 square foot	10 square chains	1 acre
9 square feet	1 square yard	640 acres	1 square mile
30¼ square yards, 272¼ square feet	1 square rod or pole	30 acres	1 yard of land
		100 acres	1 hide of land
40 square rods	1 square rood	40 hides	1 barony
4 square roods, 160 square rods, 4840 square yards	1 acre		

Cubic Measure.

1728 cubic inches	1 cubic foot	27 cubic feet	1 cubic yard

Miscellaneous Weights and Measures.

1 stone	14 pounds	1 seam of glass	120 lb.
1 score	20 pounds	1 faggot of steel	120 lb.
1 gross	12 dozen	1 ton of coal	10 sacks
1 quire	24 sheets	1 ton of Portland cement.	10 sacks or 6 casks
1 ream	20 quires		
1 cord of wood	128 cube feet	1 barrel of tar	25 gallons

TABLE OF FACTORS FOR CALCULATING EQUIVALENTS OF WEIGHT, VOLUME, LENGTH, ETC.

To convert	grammes . .	to pounds,	multiply by	0·0022
,,	,, . .	to grains,	,,	15·432
,,	,, . .	to ounces,	,,	0·0353
,,	grains . . .	to grammes,	,,	0·0648
,,	ounces . . .	to ,,	,,	28·349
,,	pounds . . .	to ,,	,,	453·715
,,	kilogrammes .	to pounds,	,,	2·204
,,	,, .	to ounces,	,,	35·3
,,	litres . . .	to gallons,	,,	0·22
,,	,, . . .	to fluid ounces,	,,	35·3
,,	,, . . .	to pints,	,,	1·76
,,	,, . . .	to cubic feet,	,,	0·0354
,,	,, . . .	to cubic inches,	,,	61·027
,,	gallons . . .	to cubic feet,	,,	0·1605
,,	,, . . .	to litres,	,,	4·5371
,,	pints . . .	to ,,	,,	0·5679
,,	,, . . .	to cubic centimetres,	,,	568·1818
,,	,, . . .	to cubic inches,	,,	34·67
,,	cubic metres .	to gallons,	,,	220·4
,,	,, .	to pints,	,,	1763·2
,,	,, .	to fluid ounces,	,,	35264·0
,,	,, .	to cubic centimetres,	,,	1000000·0
,,	cubic feet . .	to cubic metres,	,,	0·0283
,,	,, . .	to litres,	,,	28·318
,,	,, . .	to gallons,	,,	6·2322
,,	fluid ounces .	to cubic inches,	,,	1·7299
,,	,, .	to cubic centimetres,	,,	28·35
,,	square feet . .	to square metres,	,,	0·0929
,,	,, . .	to square yards,	,,	0·111
,,	square metres .	to square feet,	,,	10·7641
,,	inches . . .	to metres,	,,	0·0254
,,	,, . . .	to millimetres,	,,	25·4
,,	metres . . .	to inches,	,,	39·37
,,	,, . . .	to feet,	,,	3·28
,,	feet	to miles,	,,	0·000187
,,	yards . . .	to ,,	,,	0·00057
,,	,, . . .	to centimetres,	,,	91·44
,,	centimetres .	to inches,	,,	0·3937
,,	millimetres .	to ,,	,,	0·03937
,,	kilometres . .	to miles,	,,	1·6
,,	square kilometres	to square miles,	,,	2·5899
,,	hectares . .	to acres,	,,	0·4046

THE CHEMICAL SYMBOLS AND ATOMIC WEIGHTS OF ELEMENTARY BODIES.

Names of elements.	Chemical symbols.	Atomic weights.	Names of elements.	Chemical symbols.	Atomic weights.
Aluminium .	Al	27·5	Nitrogen .	N	14·0
Antimony .	Sb	120·0	Oxygen .	O	16·0
Arsenic . .	As	75·0	Palladium .	Pd	105·7
Barium . .	Ba	137·0	Phosphorus	P	31·0
Bromine . .	Br	80·0	Platinum .	Pt	197·2
Cadmium .	Cd	112·0	Potassium .	K	39·0
Calcium . .	Ca	40·0	Rubidium .	Rb	85·3
Carbon . .	C	12·0	Selenium .	Se	78·8
Chlorine . .	Cl	35·5	Silicon . .	Si	28·0
Chromium .	Cr	52·5	Silver . .	Ag	108·0
Cobalt . .	Co	59·0	Sodium . .	Na	23·0
Copper . .	Cu	63·2	Strontium .	Sr	87·4
Fluorine . .	F	19·0	Sulphur .	S	32·0
Gold . . .	Au	196·2	Tantalum .	Ta	182·0
Hydrogen .	H	1·0	Tellurium .	Te	125·0
Iodine . .	I	126·6	Thallium .	Tl	203·7
Iridium . .	Ir	192·7	Thorium .	Th	231·5
Iron . . .	Fe	56·0	Tin . . .	Sn	118·0
Lead . . .	Pb	206·5	Titanium .	Ti	48·0
Lithium . .	Li	7·0	Tungsten .	W	184·0
Magnesium .	Mg	24·0	Uranium .	U	240·0
Manganese .	Mn	55·0	Vanadium .	V	51·3
Mercury . .	Hg	200·0	Yttrium .	Y	88·0
Molybdenum	Mo	95·5	Zinc . .	Zn	65·0
Nickel . .	Ni	59·0	Zirconium .	Zr	89·4

PREPARATION OF CULTURE MEDIA.

A variety of culture media have been alluded to in the text, particularly in the section which deals with the bacteriological examination of a water sample. The manner of preparing but one has been given in detail—namely, the bile-salt glucose broth used in MacConkey's method. Details as to some other media in common use are given below.

Nutrient Broth.—One pound of meat, free from fat, must be minced finely, then infused in a litre of cold distilled water, and allowed to stand in a cold place for twenty-four hours. The whole mass is then strained through a cloth, and distilled water added to the filtrate so as to make up the volume of fluid to one litre. Ten grammes of peptone and five grammes of common salt are now added to the litre of fluid, which is then boiled in the steam sterilizer for one hour at 100° C. Owing to the presence of acid phosphates of potassium and sodium, weak acids of the glycolic series and organic compounds in which the acid character predominates, this meat extract will be more or less acid. It will always react acid to phenolphthalein, but occasionally reacts neutral or even alkaline to litmus. Further, if exactly neutral to litmus, it will be found to react acid to phenolphthalein. The main reason for this is due to the fact that litmus is insensitive to many weak organic acids, the presence of which is

readily indicated by phenolphthalein. Estimate the reaction of the medium by placing 25 c.c. of it into a clean beaker, running in 0·5 c.c. of phenolphthalein solution, immersing the beaker in a water-bath, and raising to the boil. Now cautiously run in to the medium in the beaker, standing in the water-bath at the boil, some $\frac{N}{10}$NaOH solution, until the end point is reached as indicated by the development of a faint pink tinge. Note the amount of deci-normal soda solution used. It is convenient to use broth media standardized to +10, the symbol + meaning acid and – meaning alkaline, in both cases to phenolphthalein as indicator. Briefly, the method of standardizing a litre of broth or other medium to +10 consists in subtracting 10 from the initial *titre* of the medium mass; the remainder indicates the number of cubic centimetres of normal soda solution that must be added to the medium, per litre, to render the reaction +10. Say, 25 c.c. of the medium have required the addition of 5·65 c.c. $\frac{N}{10}$NaOH solution to neutralize it, and therefore 1000 c.c. will require 226 c.c. or 22·6 c.c. of $\frac{N}{1}$NaOH solution. The initial *titre*, then, of this medium will be +22·6, and as such requires the addition of (22·6 – 10)12·6 c.c. of normal NaOH per litre to leave its finished reaction at +10. To be strictly accurate, allowance must be made for the volume of medium used in the titrations, and remembrance made that the remainder of medium to be neutralized does not now measure a full litre. Say, three titrations were made, each with 25 c.c., then the original bulk of the medium will be but 925 c.c., requiring but 11·65 c.c. of normal NaOH to make it +10.

Having brought the medium to the required reaction, heat again for half an hour at 100° C., to complete the precipitation of phosphates. Filter through Swedish filter-paper into sterile tubes (10 c.c. in each). Plug the tubes with cotton wool, and then sterilize these in the steamer on three successive days for twenty minutes.

Glucose and Lactose Broth.—These are simply the above ordinary broths containing 1 or 2 per cent. of either grape or milk sugar. The steps in the preparation are the same as those just described.

Nutrient Gelatine.—This is made by adding 10 to 15 per cent. of best gold-label gelatine, cut into small pieces, to ordinary broth prepared as above, and then melting it by steaming at 100° C. for one hour. Estimate the reaction of the medium mass, as explained for broth, then add sufficient normal soda solution to render the reaction of the calculated bulk of medium +10. Replace in the steamer, and keep at 100° C. for twenty minutes, to precipitate all the phosphates. Allow to cool to 60° C. Add the whites of two eggs for each litre of medium, replace in steamer at 100° C. for half an hour; then filter through Chardin paper into sterile tubes. Sterilize these at 100° C. for twenty minutes on each of three consecutive days.

Glucose and Lactose Gelatine are made in the same way, adding 1 to 2 per cent. of the respective sugars.

Nutrient Agar-Agar.—Add 15 grms. of agar, cut into very fine fragments, to a litre of ordinary broth, prepared as explained. Dissolve by heating at 100° C. for an hour and a half. Estimate the reaction of the medium mass as explained under the head of "Broth;" then add sufficient normal soda solution to render the reaction of the calculated bulk of the medium +10. Replace in the steamer for twenty minutes to complete the precipitation of phosphates. Allow the medium to cool to 60° C., add whites of two eggs, replace in steamer, and keep at 100° C. for half an hour. Now filter through Chardin paper, by the aid of a hot-water funnel, into sterile tubes. Sterilize these in the steamer at 100° C. for half an hour on each of three successive days.

Glycerine Agar is made in the same way, 6 per cent. of glycerine being added after filtration.

Glucose and Lactose Agar are made as under ordinary agar, 2 per cent. of the respective sugars being added, as the case may be. If required to be tinted with neutral red, 2 per cent. of a half per cent. solution of neutral red is added before filtration.

Peptone Solution.—One to 2 per cent. of Witte's peptone with 0·5 per cent. of common salt are dissolved in distilled water by heating. The fluid is then filtered, placed in tubes, and sterilized. In this medium, cholera vibrios grow with great rapidity. It is also much used for testing the formation of indol by different bacteria.

Glucose Peptone Solution.—Made by dissolving, by means of heat, 1 grm. of glucose, 1 grm. of peptone, and ½ grm. of salt in 100 c.c. of distilled water. This is filtered, rendered neutral to litmus, placed in steamer at 100° C. for half an hour, then tubed into test-tubes containing inverted fermentation tubes, and sterilized for twenty minutes at 100° C. on three successive days.

Lactose Peptone Solution.—Prepared as the foregoing, substituting lactose for the glucose.

Sucrose Peptone Solution.—Prepared as the foregoing, substituting pure cane-sugar for the glucose or lactose.

Mannite Peptone Solution.—Prepared as the foregoing, substituting the alcohol mannite for one or other of the sugars.

Proskauer and Capaldi's Media.—The No. I. medium has the following composition: Asparagin and mannite of each 0·2 per cent.; potassium monophosphate, 0·2 per cent.; sodium chloride and calcium chloride of each 0·02 per cent.; and of magnesium sulphate, 0·01 per cent. The reagents are dissolved in distilled water, sterilized for an hour at 100° C. The medium is then rendered neutral to litmus by the addition of sufficient normal caustic soda solution. Sufficient litmus solution is added to give the medium a purple tint. It is now tubed and sterilized in the usual way for twenty minutes at 100° C. on three successive days.

The No. II. medium contains 2 per cent. of Witte's peptone and 0·1 per cent. of mannite dissolved in distilled water. Sterilized at 100 C. for an hour. This will be now found to be alkaline; it is next carefully rendered neutral to litmus by the addition of a saturated solution of citric acid. Litmus solution is added to give it a deep red colour. It is now tubed and sterilized in the usual way for twenty minutes at 100° C. on three successive days. These media are of great value in the differential diagnosis between the *B. coli* and the *B. typhosus*.

Milk.—Fresh milk and free from any preservative is steamed for half an hour at 100 C., and then placed in a cool place overnight for separation of cream. The milk is then siphoned off from beneath the cream, and placed in sterile tubes; if necessary, sufficient litmus solution is added to give it a purple tinge. The tubes are plugged, and then sterilized at 100° C. for twenty minutes on each of three successive days.

Potato Medium.—A large potato is well washed and scrubbed with a brush. A cylinder is then bored from its interior, and cut obliquely. The peel from the ends is cut off, and the wedges so obtained allowed to soak overnight in cold water to get rid of any excess of starch. Each wedge of potato is then placed in a test-tube, previously fitted with a pad of cotton wool at the bottom, and filled for about ½ inch in depth with distilled water. The tube is now plugged with cotton wool, and sterilized at 100° C. for twenty minutes on three successive days.

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